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(12) **United States Patent**
Mizuhashi et al.

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(54) **DISPLAY PANEL WITH TOUCH DETECTION FUNCTION, METHOD OF DRIVING THE SAME, DRIVING CIRCUIT, AND ELECTRONIC UNIT**

(58) **Field of Classification Search**
None
See application file for complete search history.

(71) Applicant: **Japan Display Inc.**, Tokyo (JP)

(56) **References Cited**

(72) Inventors: **Hiroshi Mizuhashi**, Kanagawa (JP); **Yoshitoshi Kida**, Kanagawa (JP); **Koji Noguchi**, Kanagawa (JP)

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(73) Assignee: **Japan Display Inc.**, Tokyo (JP)

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(21) Appl. No.: **14/842,291**

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Japanese Office Action issued Mar. 31, 2015 for corresponding Japanese Application No. 2011-242797.

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 14/306,633, filed on Jun. 17, 2014, now Pat. No. 9,141,247, which is a continuation of application No. 13/414,363, filed on Mar. 7, 2012, now Pat. No. 8,791,916.

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Primary Examiner — Kenneth B Lee, Jr.

(74) *Attorney, Agent, or Firm* — Michael Best & Friedrich LLP

(30) **Foreign Application Priority Data**

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Nov. 4, 2011 (JP) 2011-242797

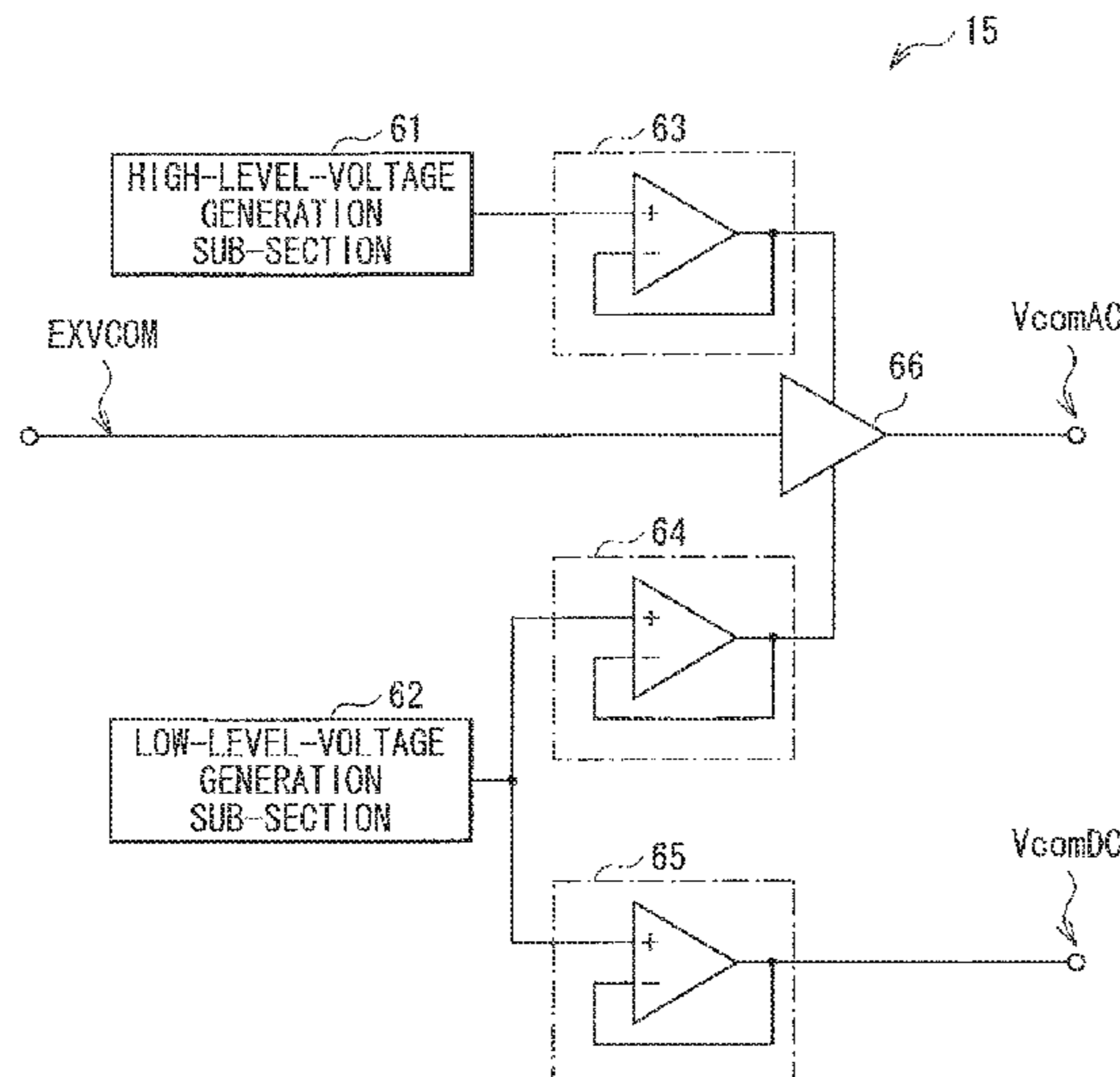
(57) **ABSTRACT**

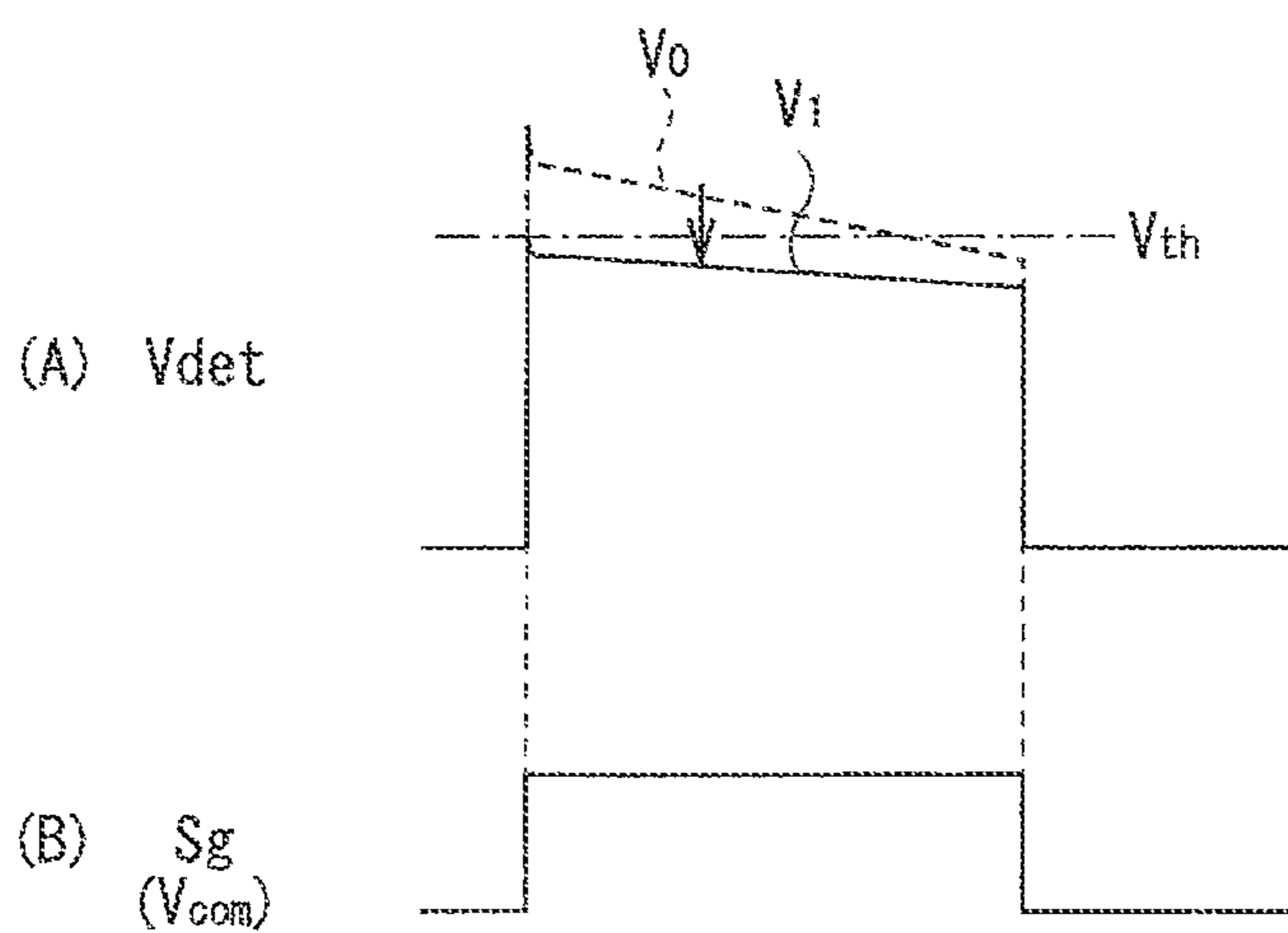
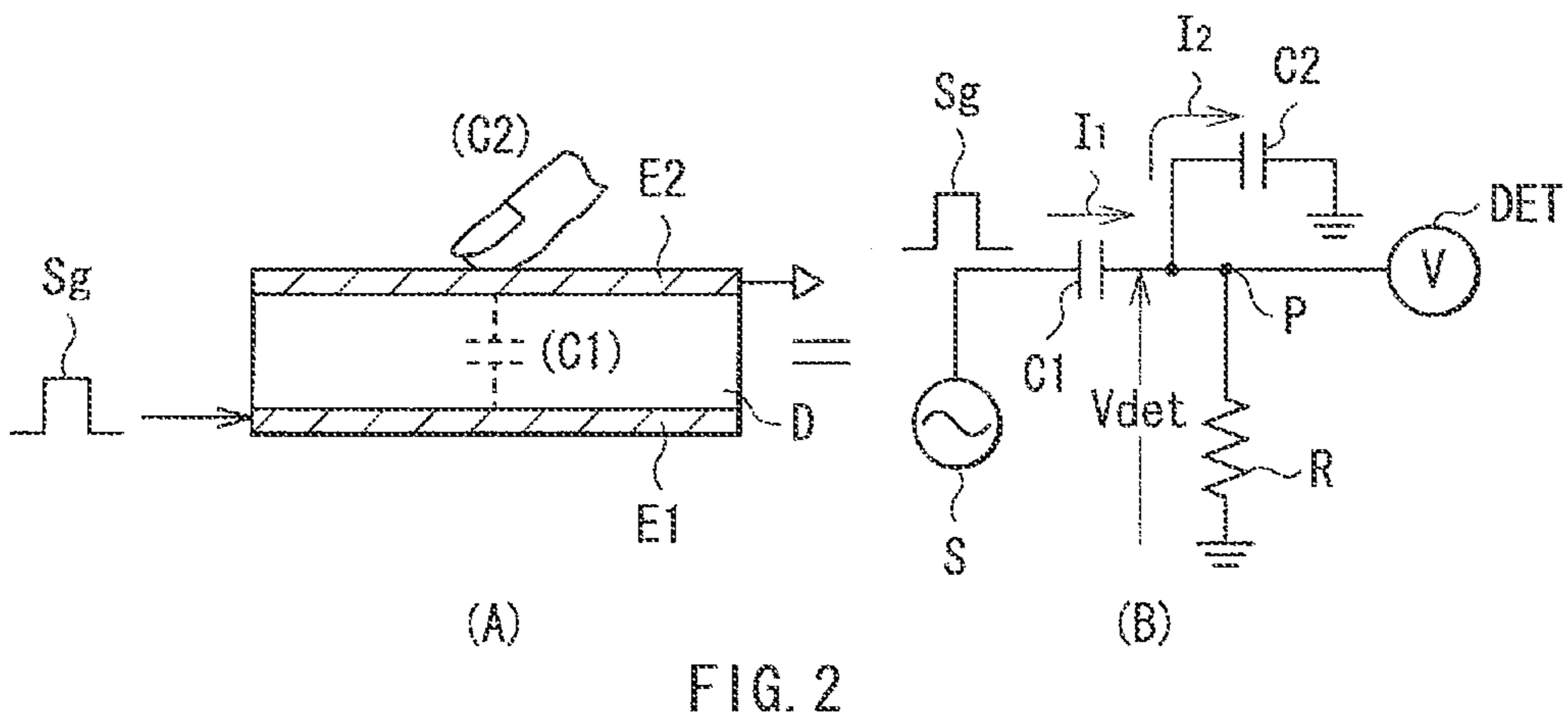
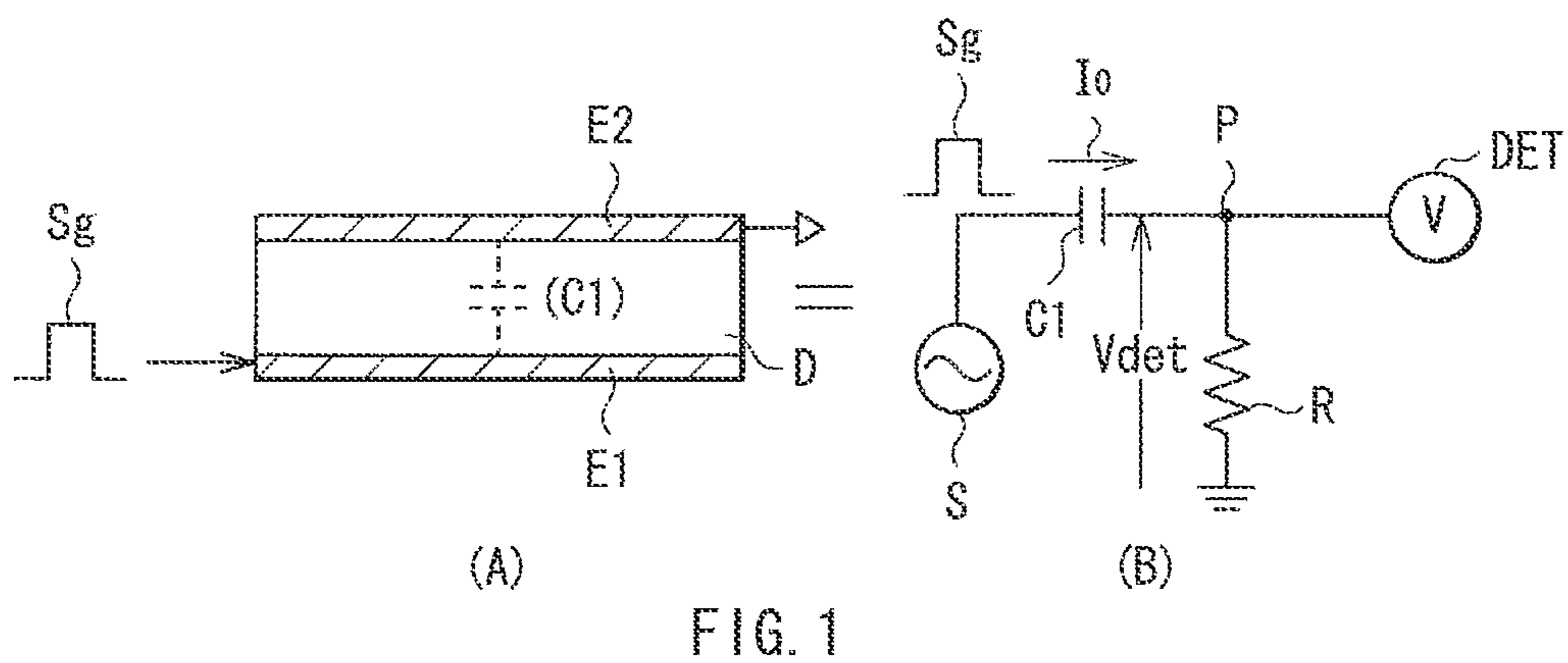
There are provide a display panel with a touch detection function, in which display operation is less affected by touch detection operation, a method of driving the display panel with a touch detection function, a driving circuit, and an electronic unit having the display panel with a touch detection function. The display panel with a touch detection function includes: one or more display elements; one or more drive electrodes; one or more touch detection electrodes; and a drive section selectively applying a DC drive signal or an AC drive signal to the drive electrodes.

(51) **Int. Cl.**
G06F 3/044 (2006.01)
G06F 3/041 (2006.01)

(52) **U.S. Cl.**
CPC **G06F 3/044** (2013.01); **G06F 3/0412** (2013.01)

8 Claims, 25 Drawing Sheets





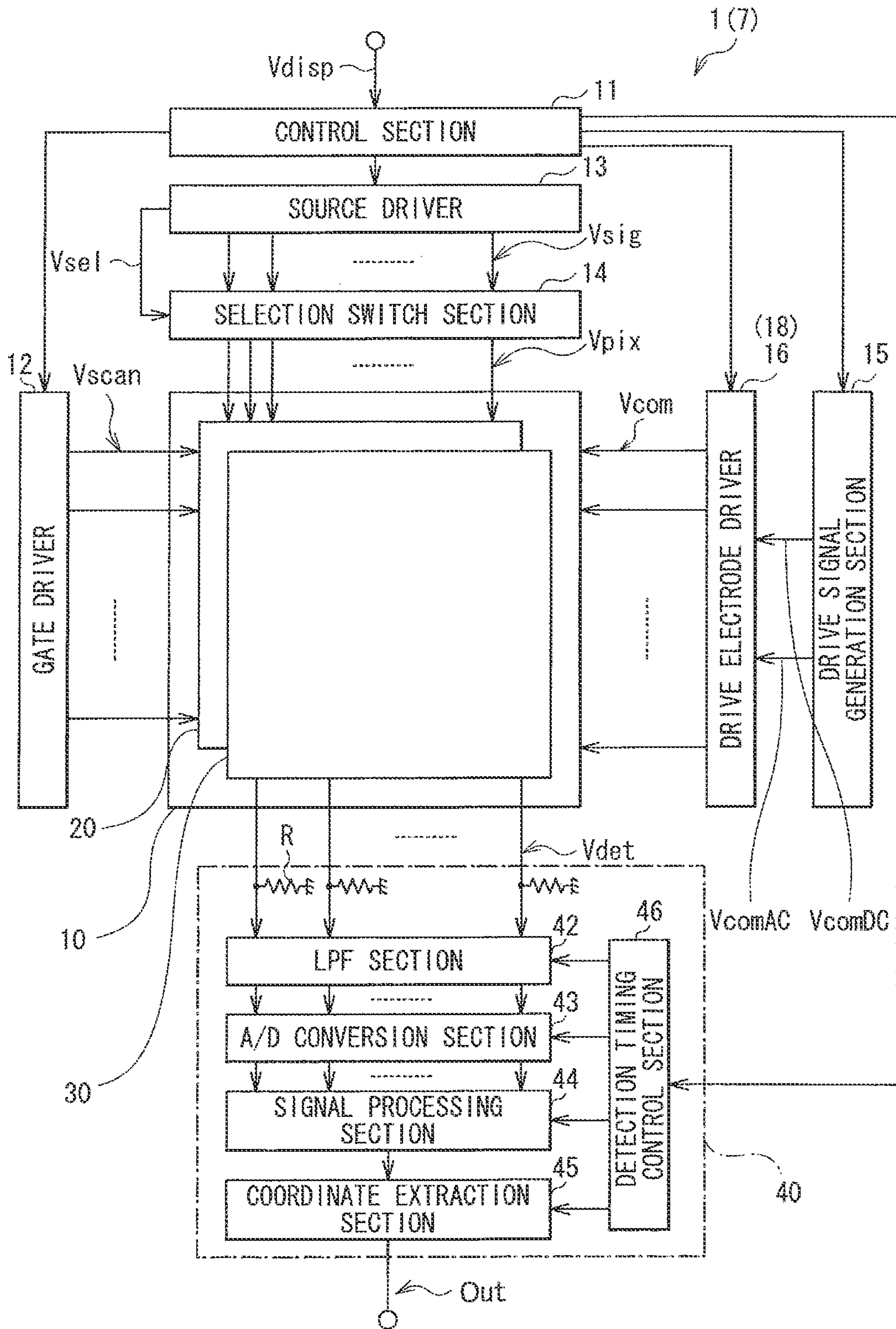


FIG. 4

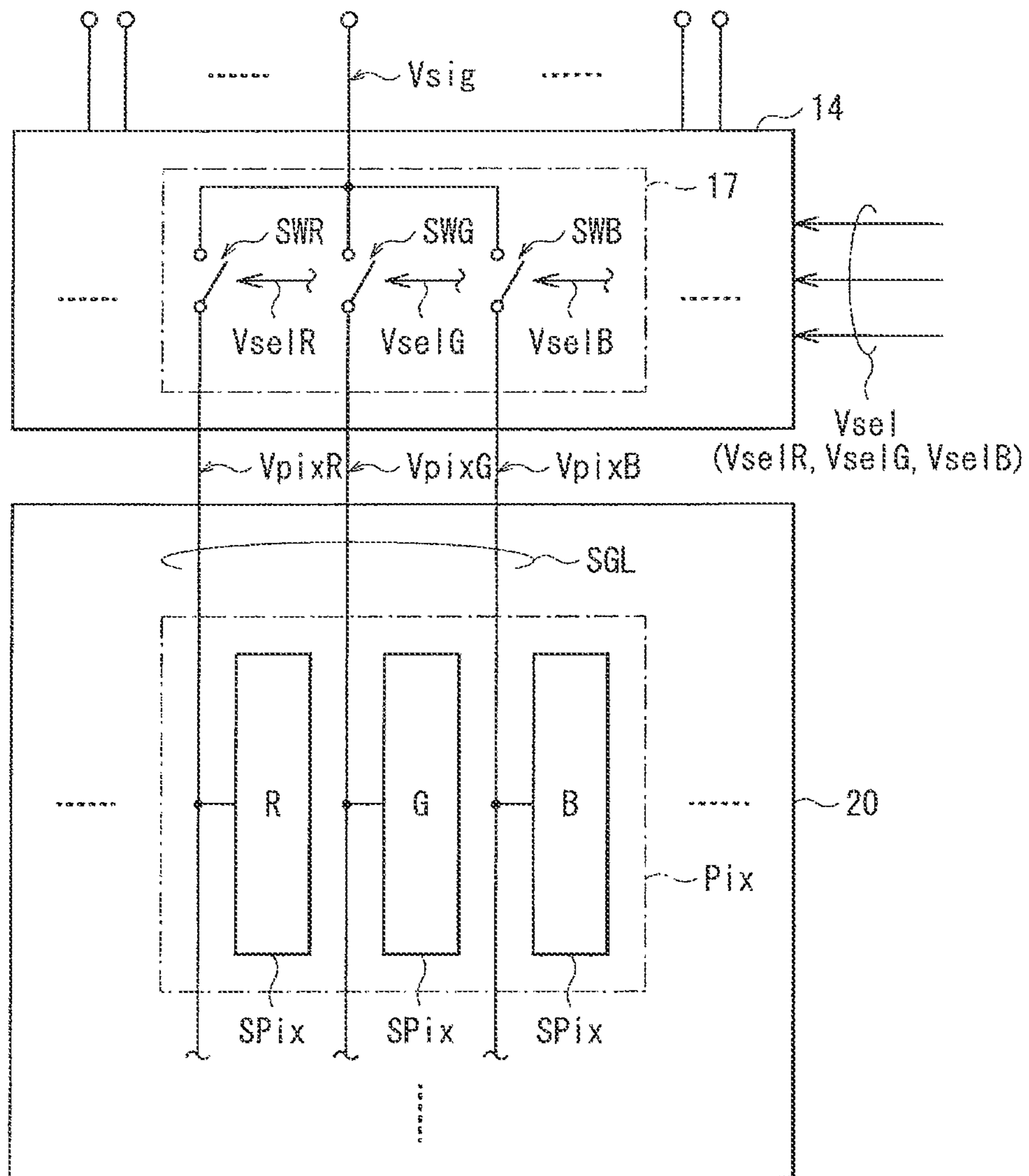


FIG. 5

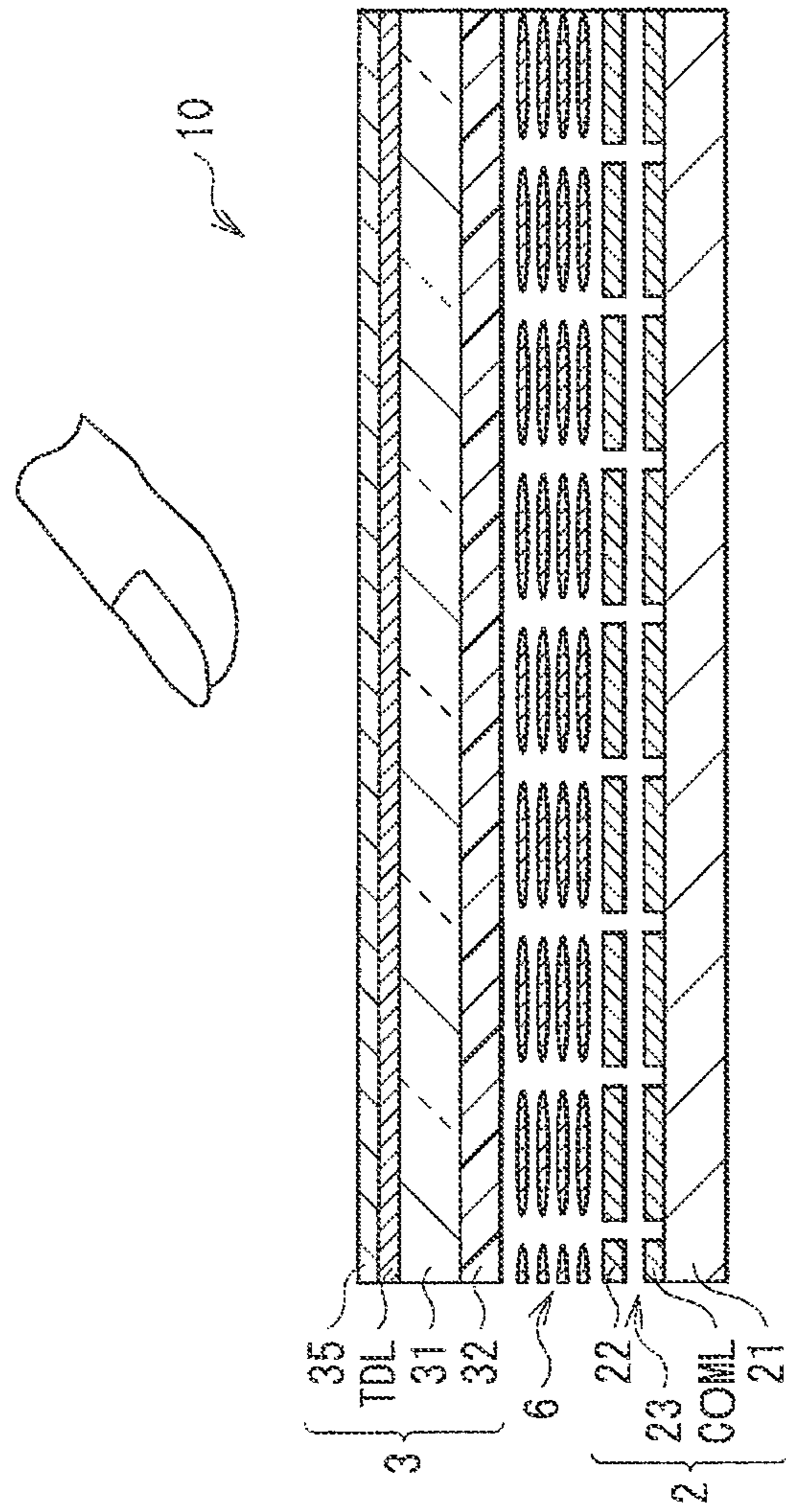


FIG. 6

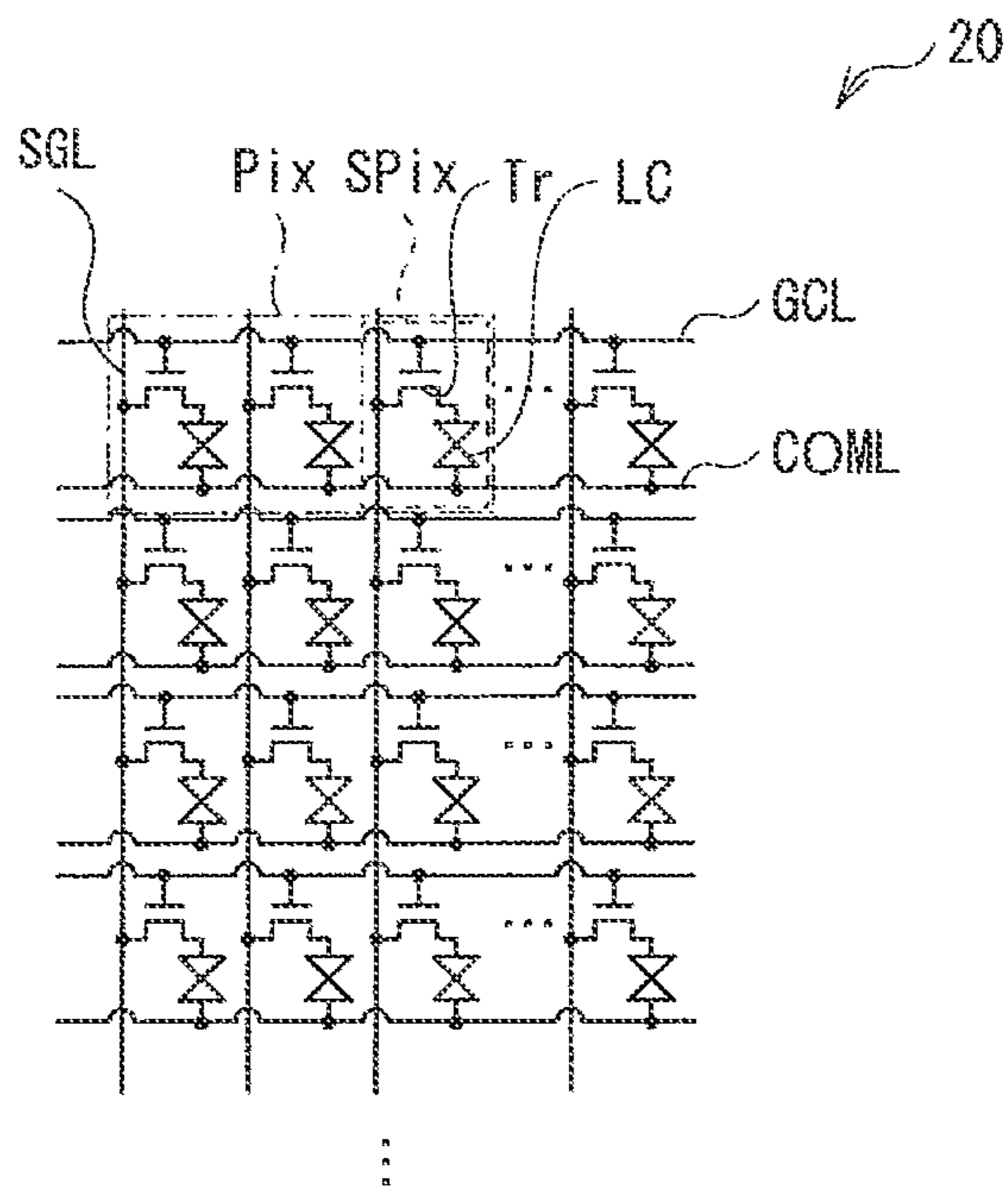


FIG. 7

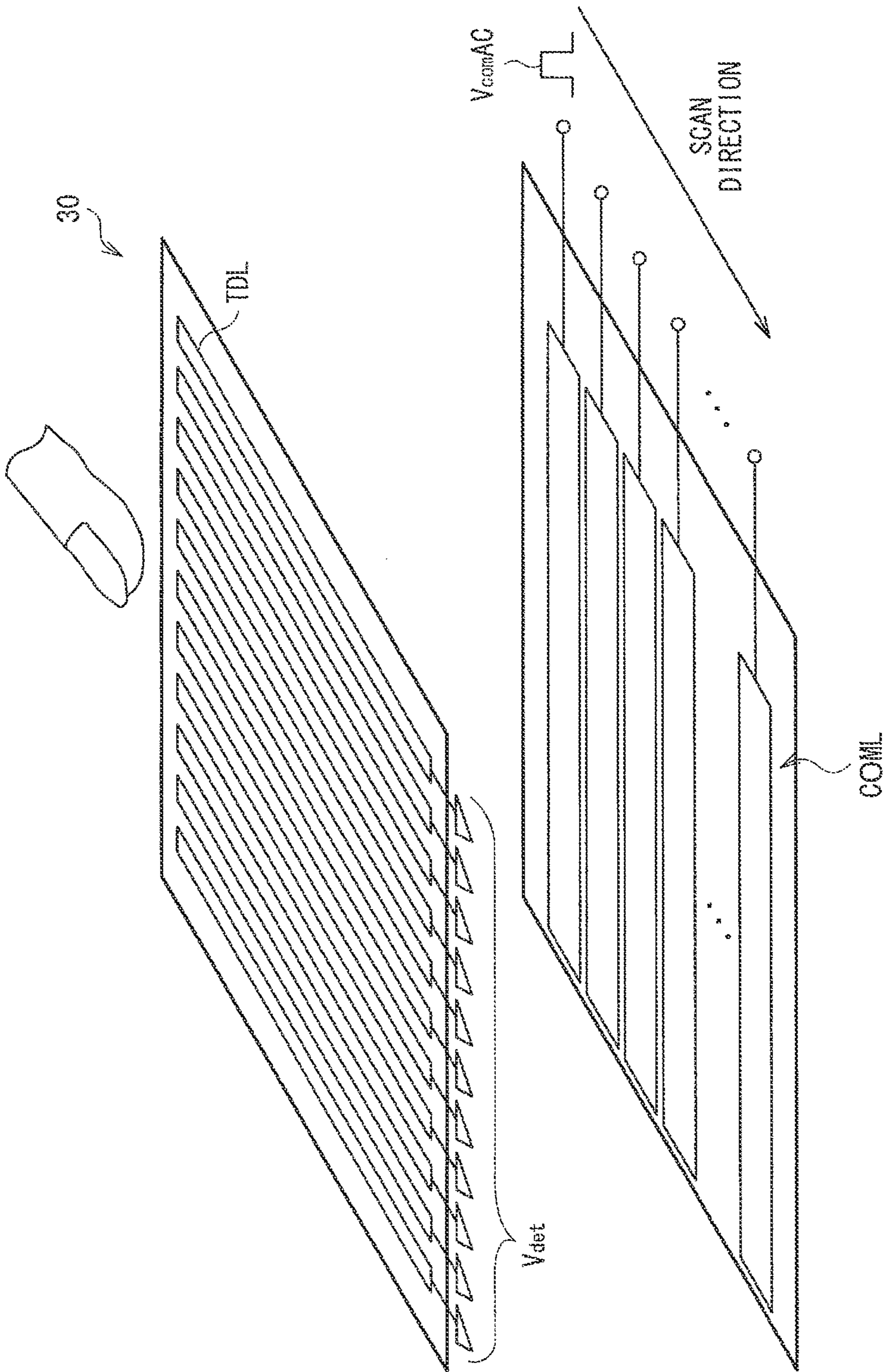


FIG. 8

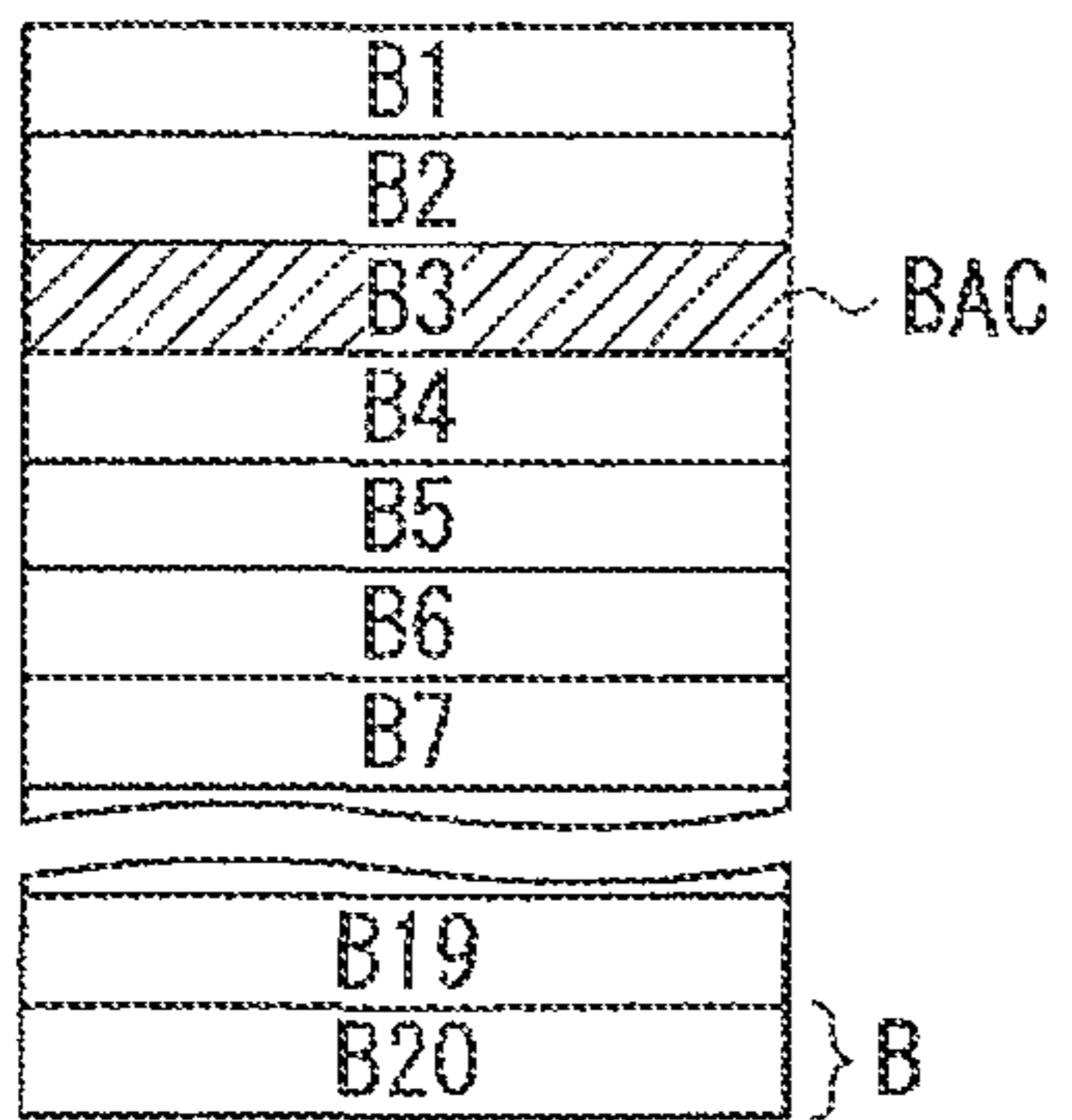


FIG. 9A

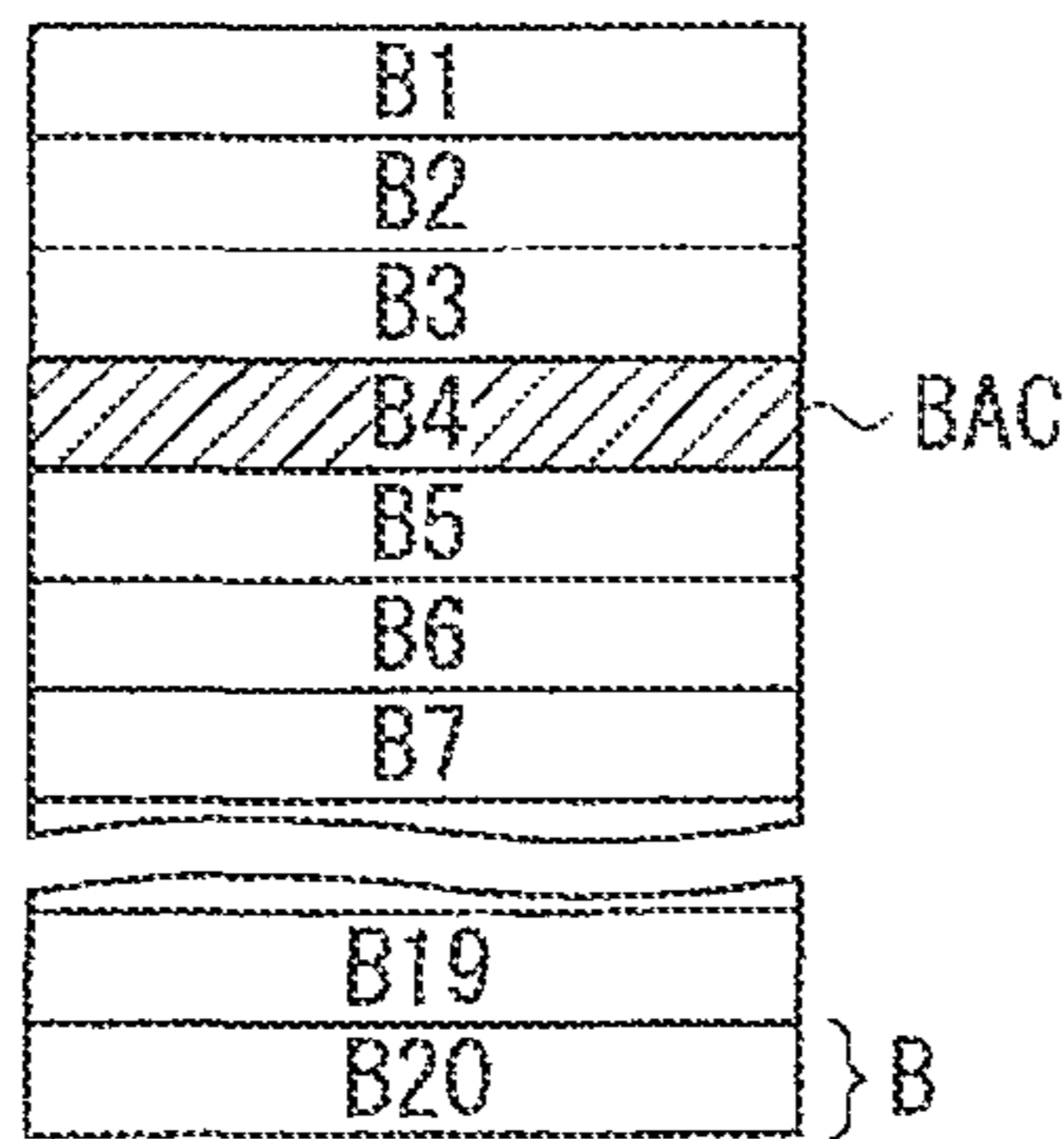


FIG. 9B

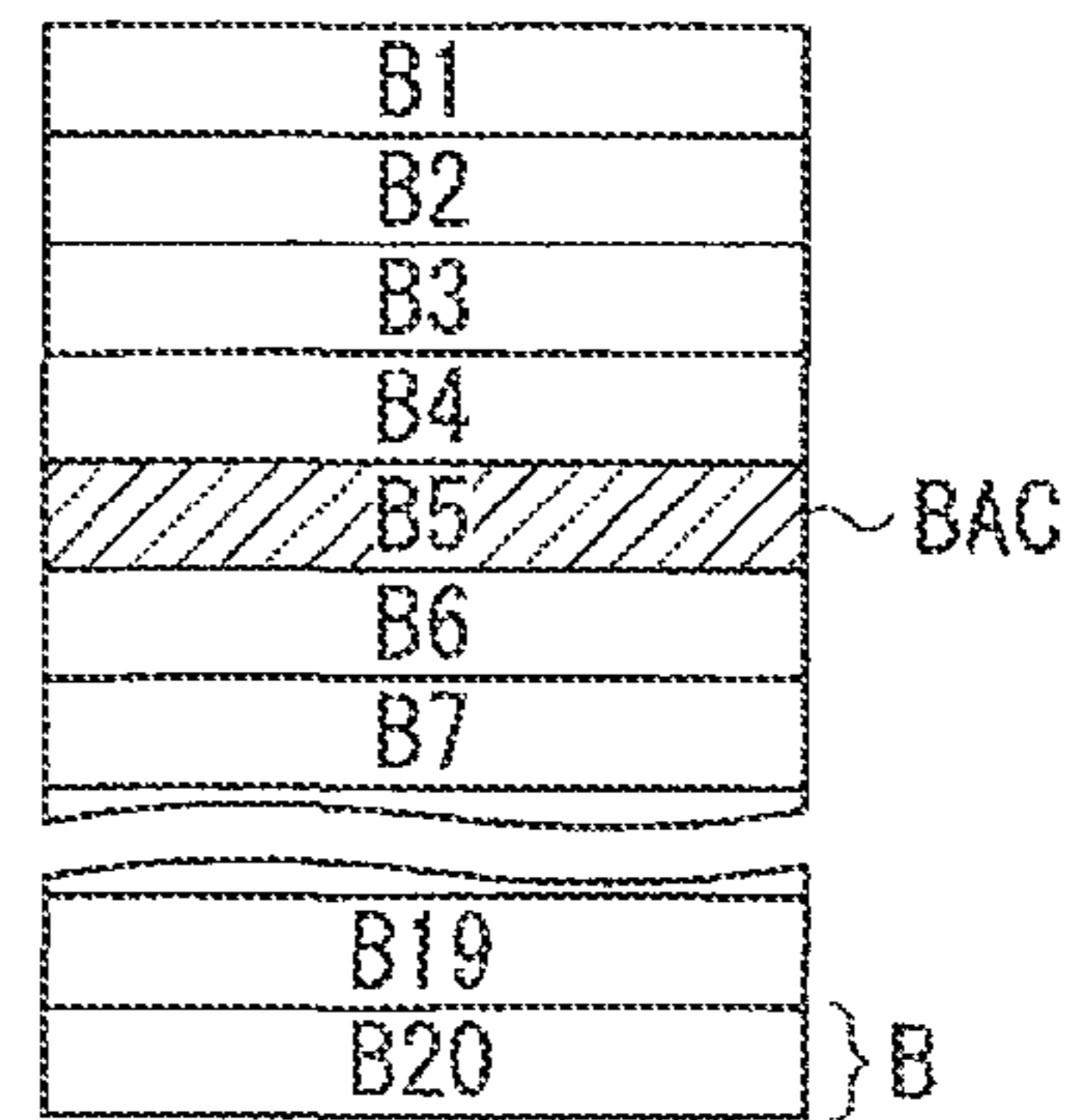


FIG. 9C

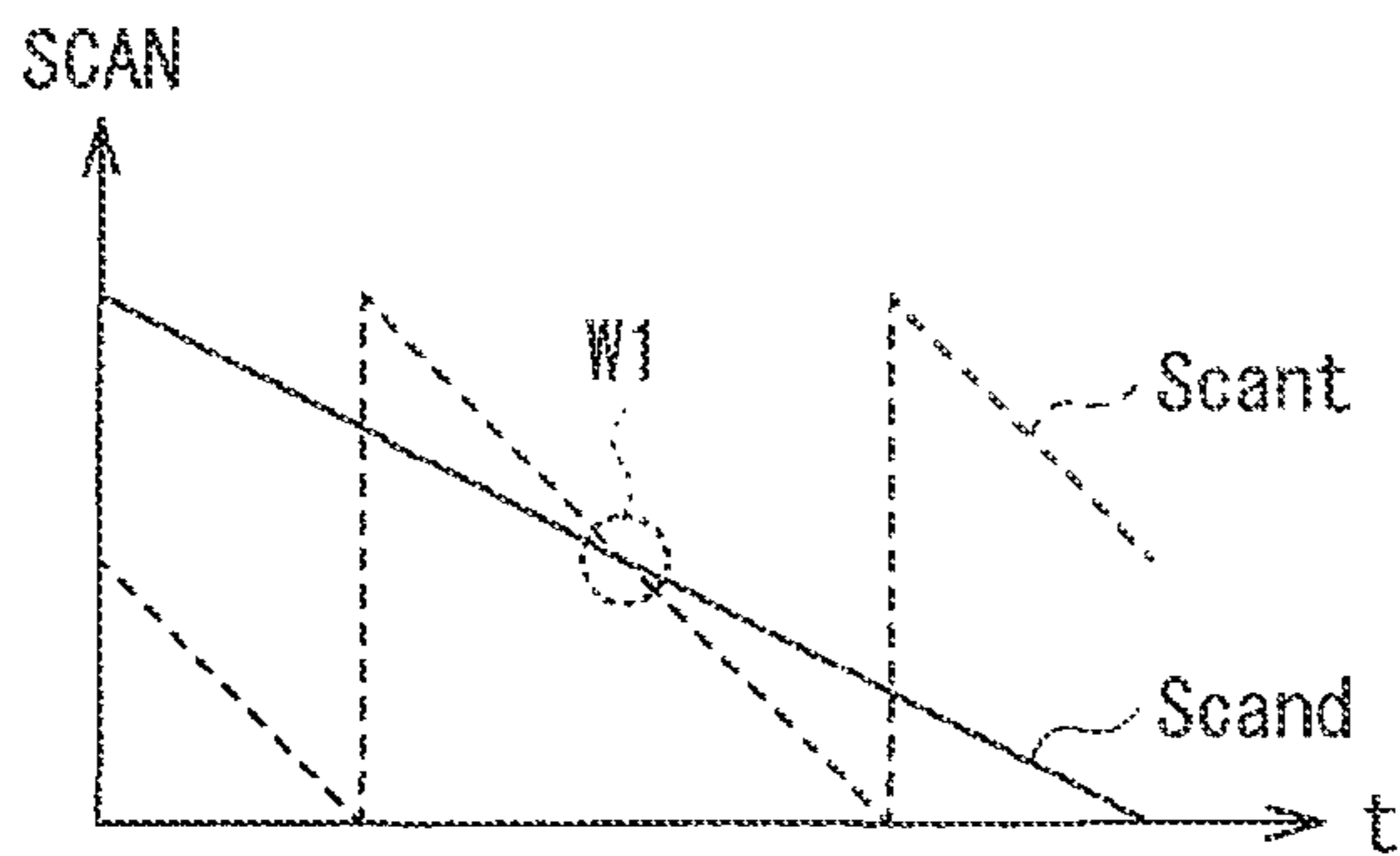


FIG. 10

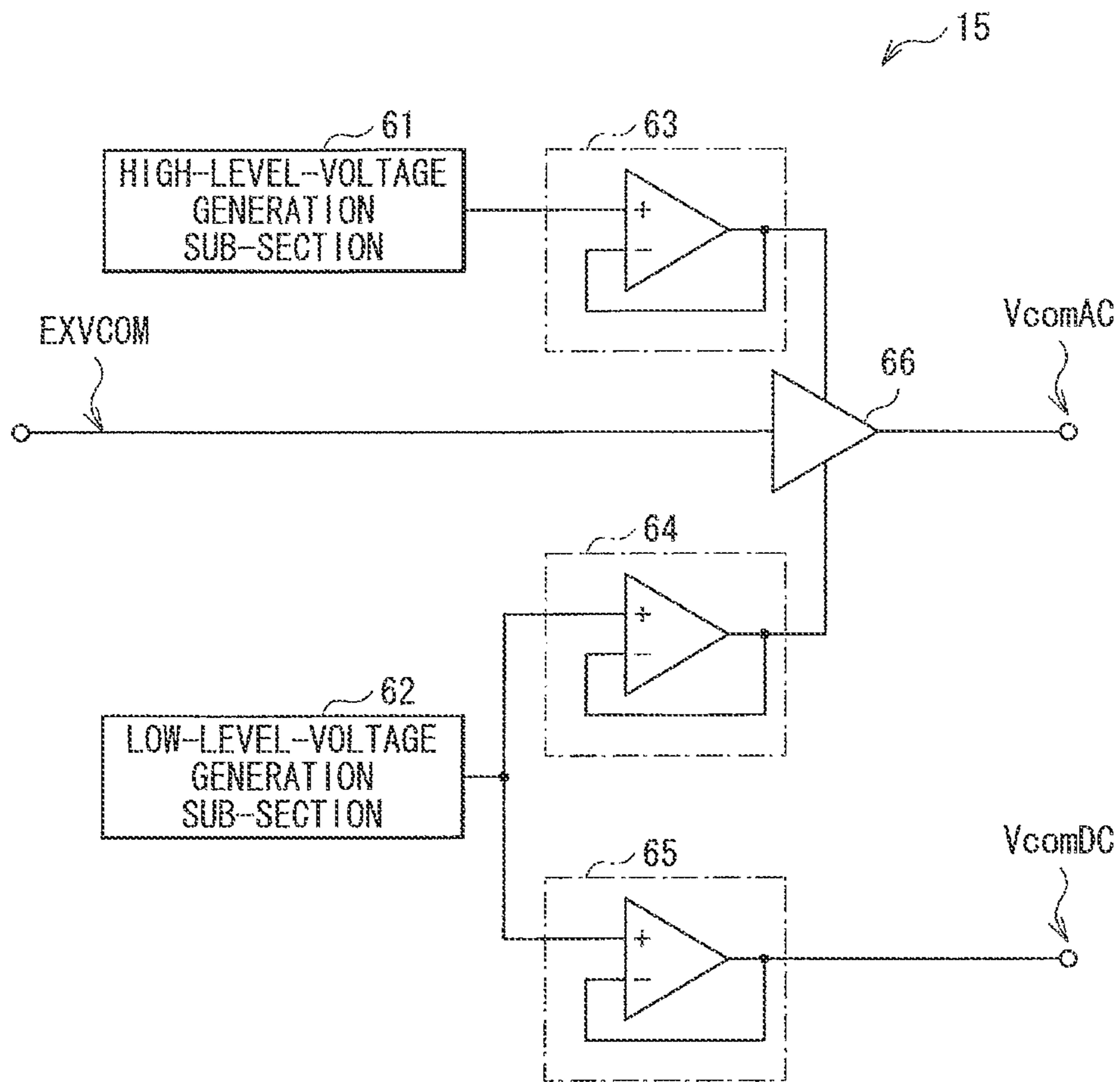


FIG. 11

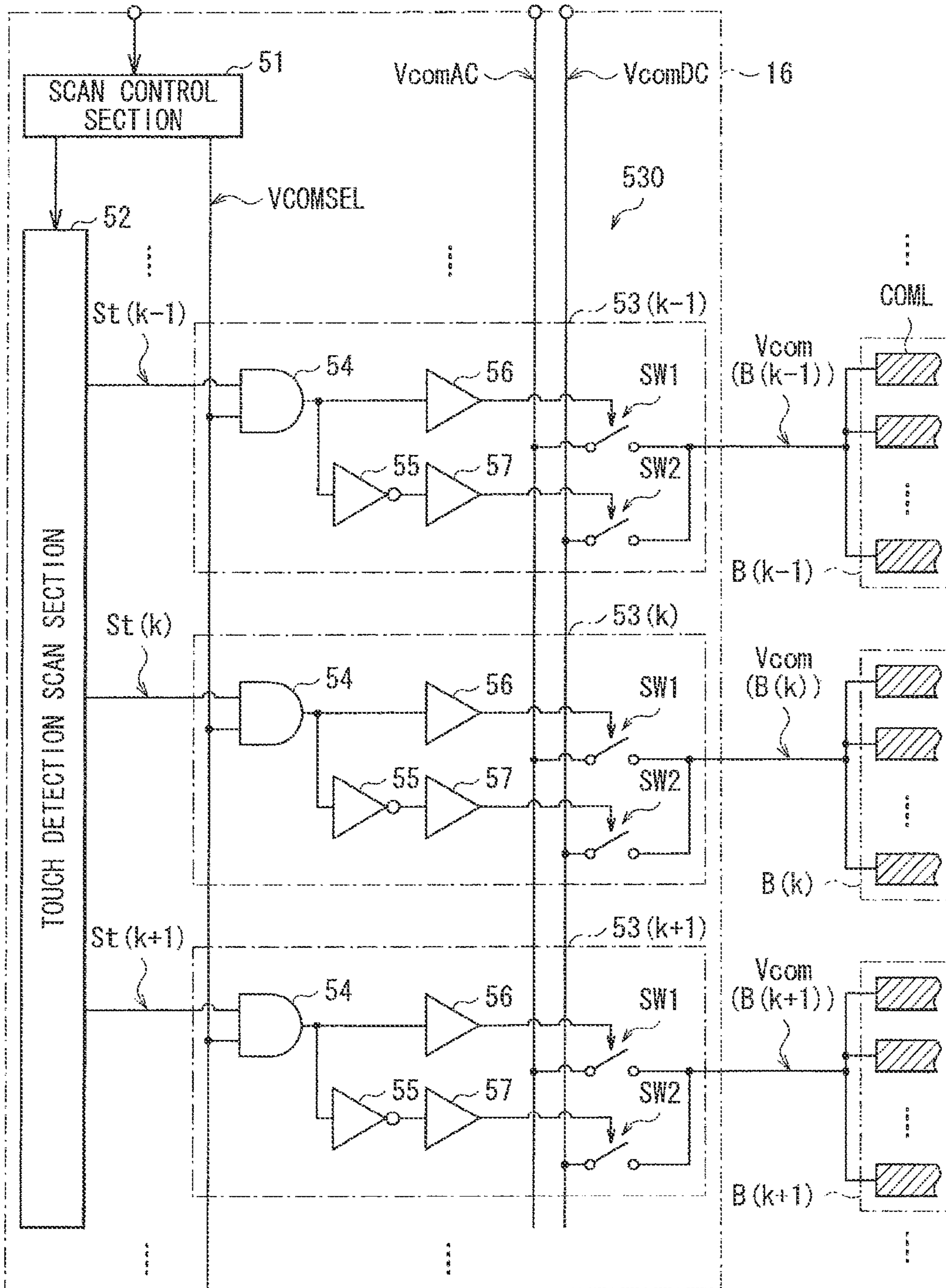


FIG. 12

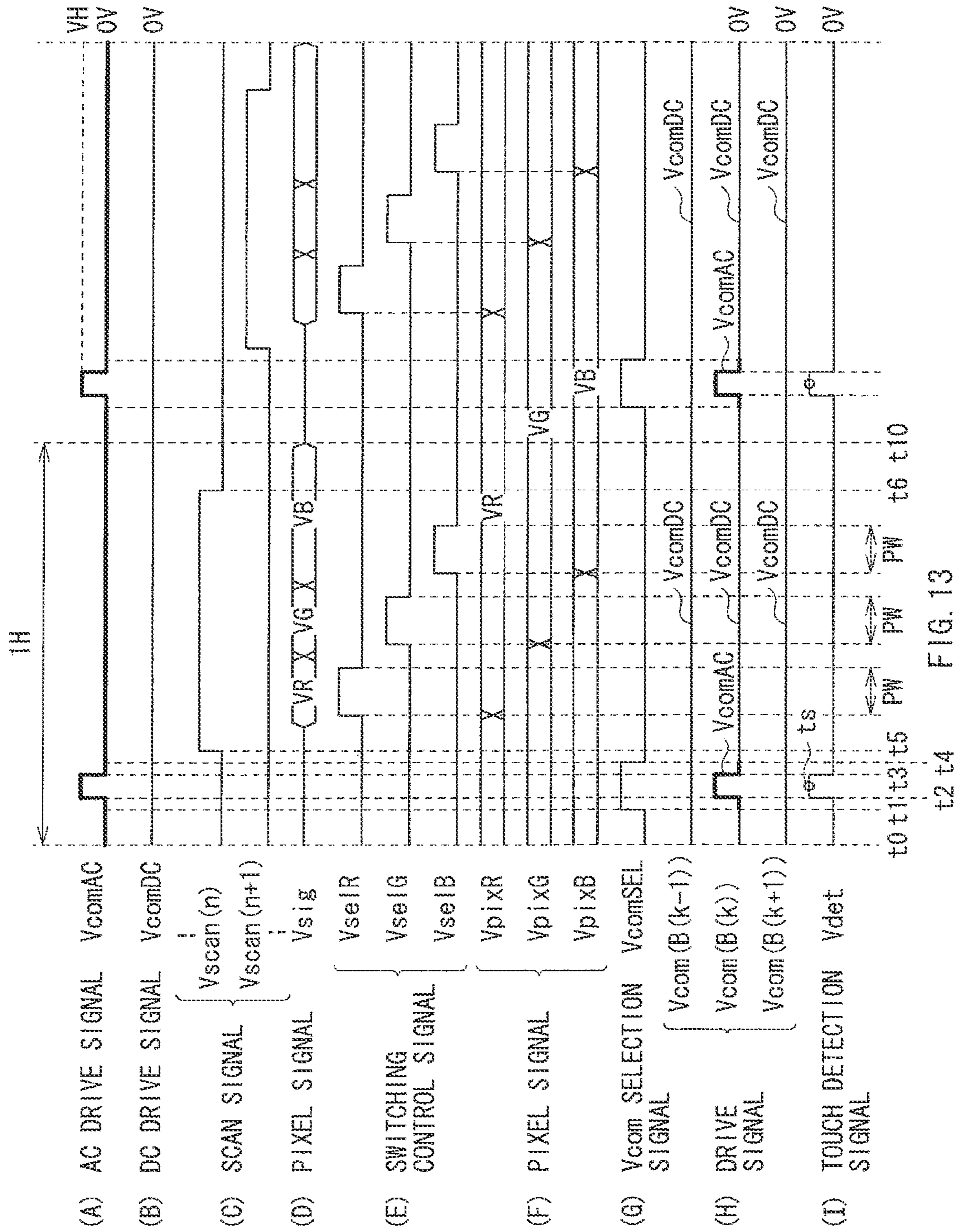


FIG. 13

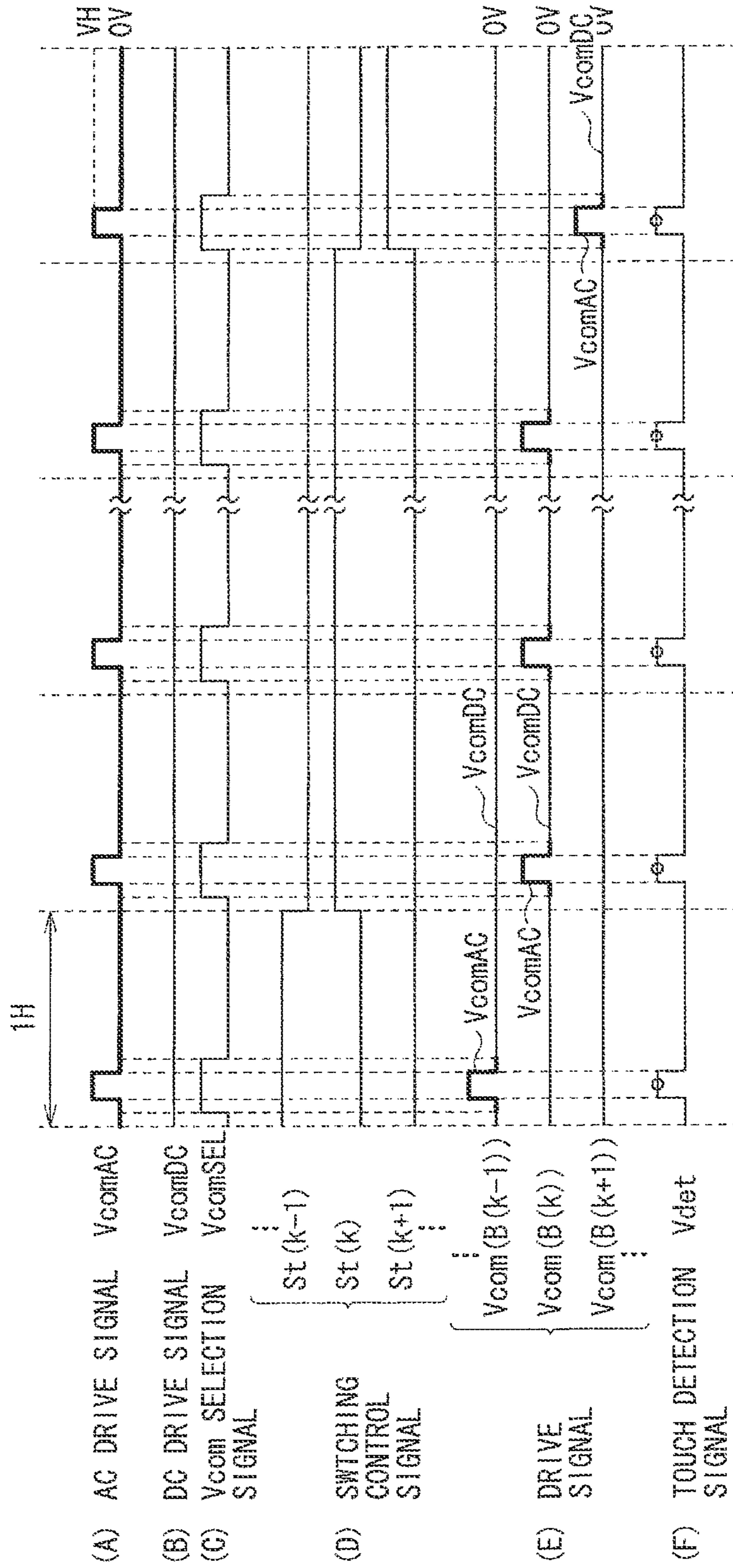


FIG. 14

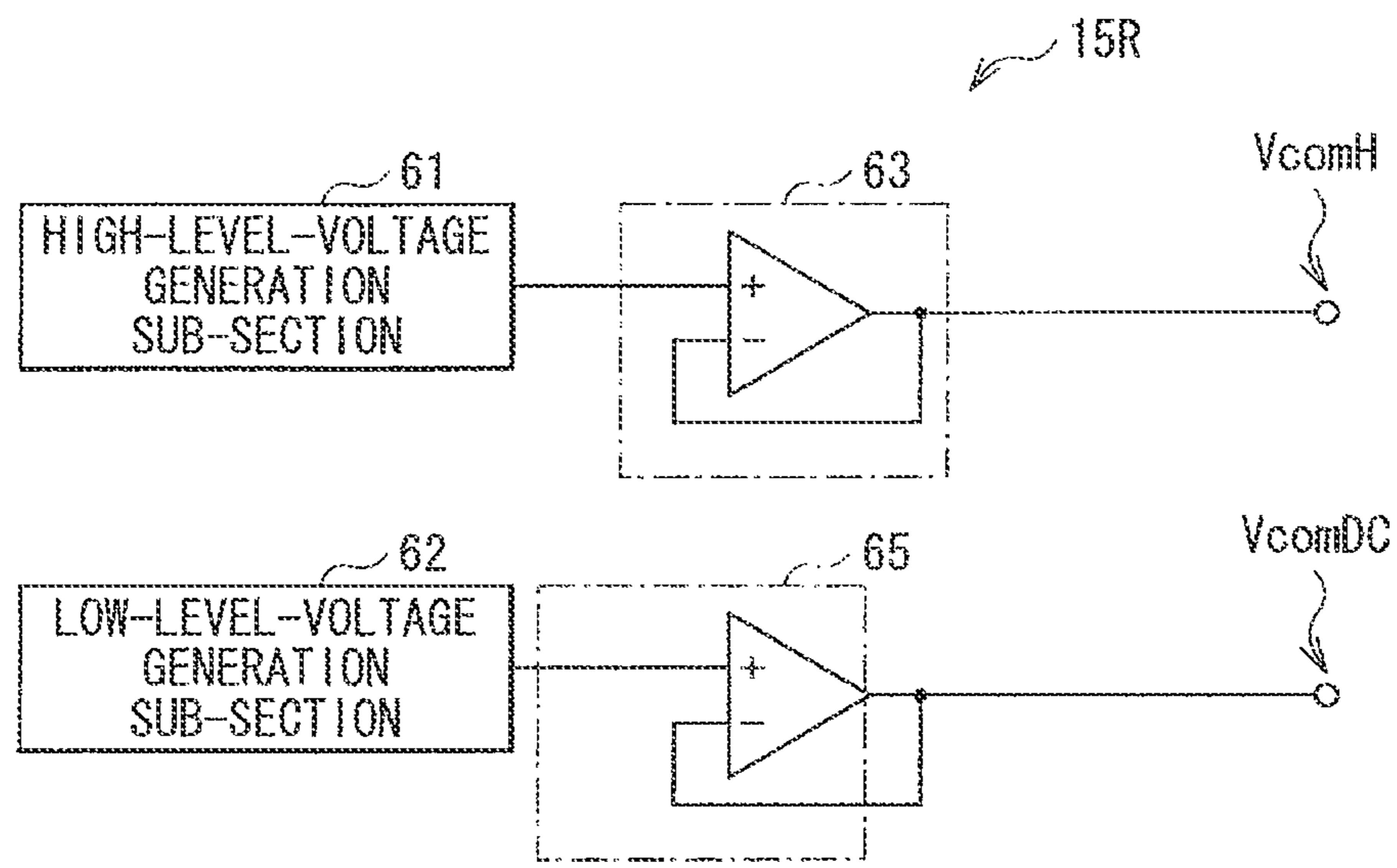


FIG. 15

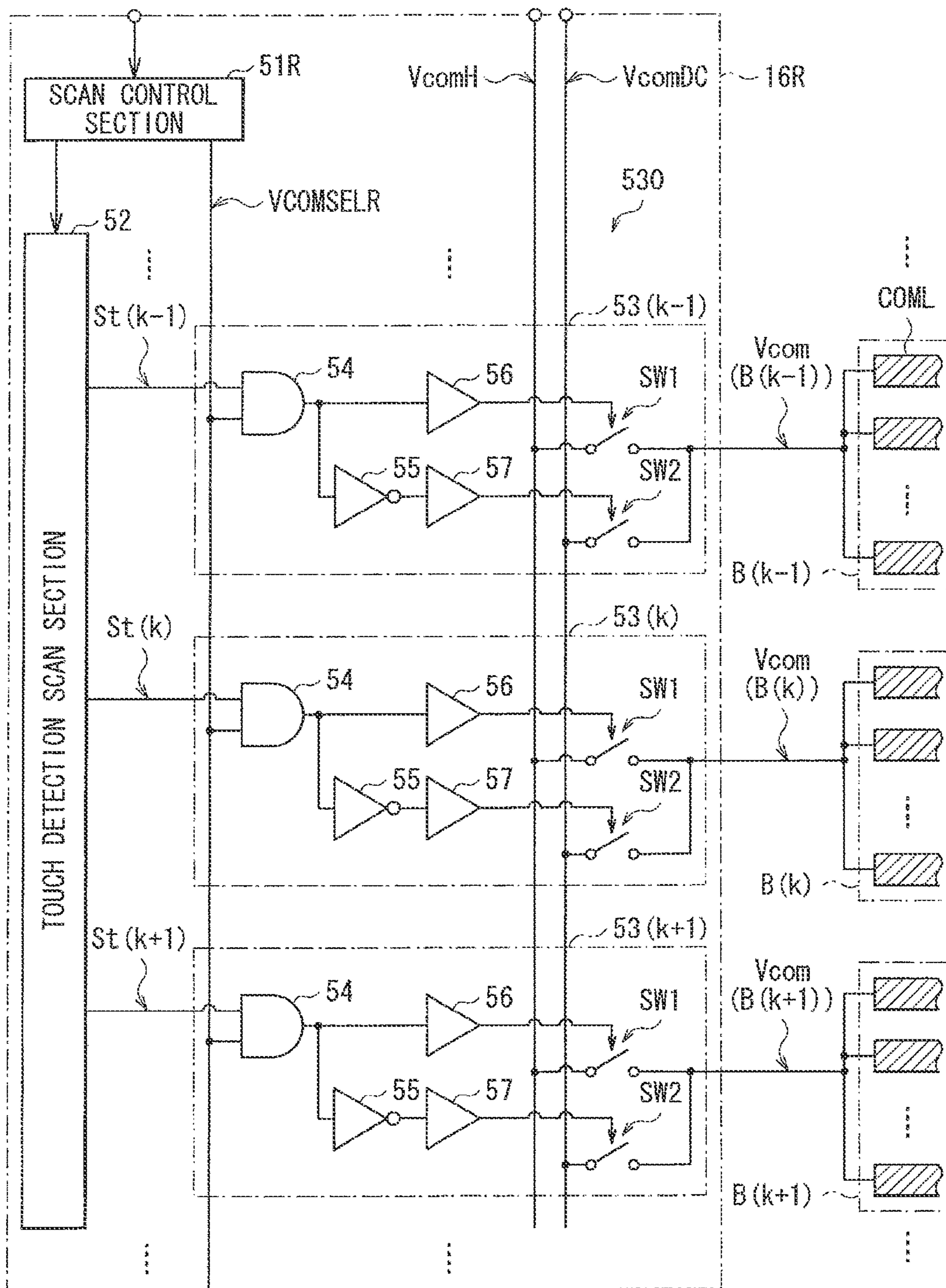
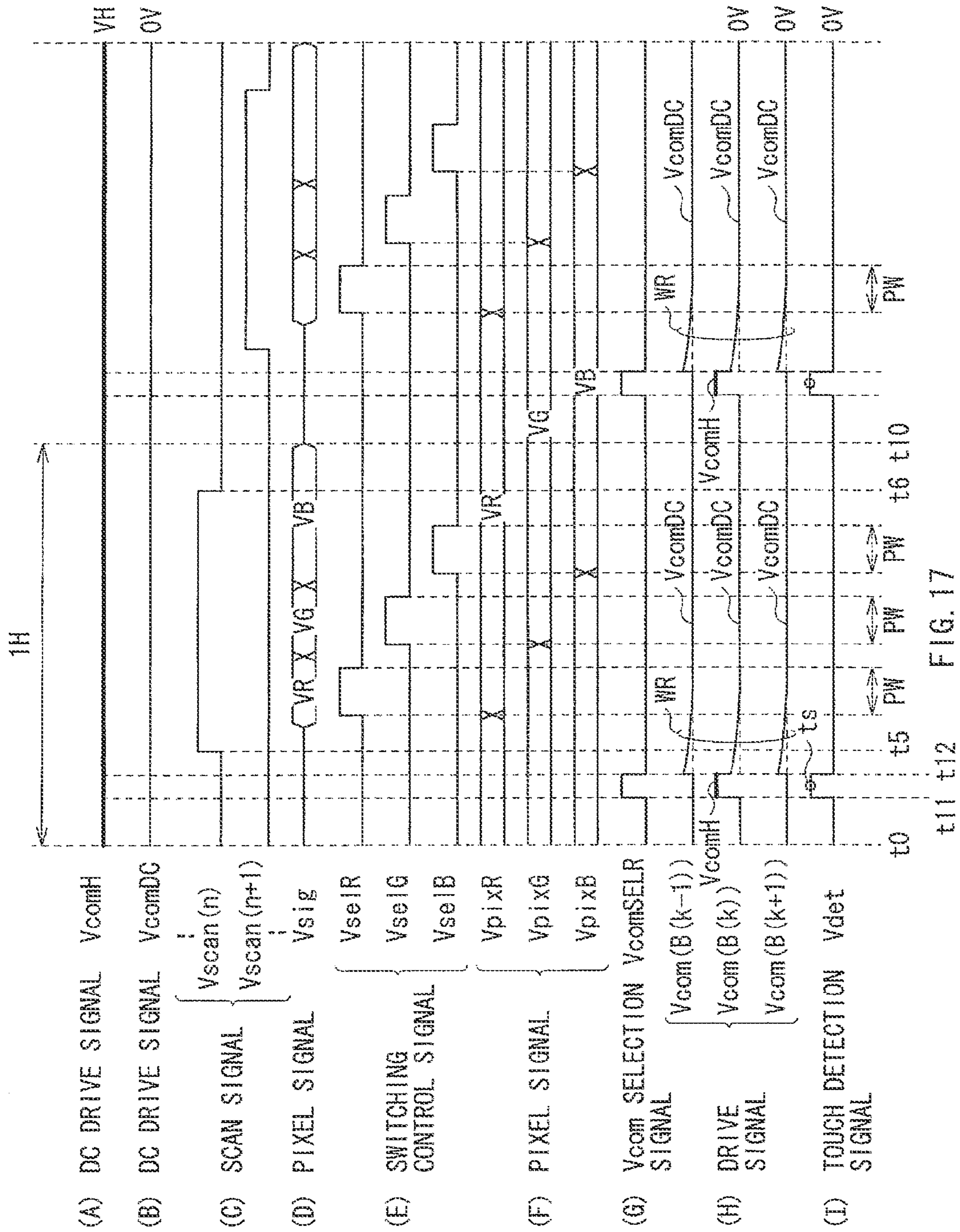


FIG. 16



t11 t12 FIG. 17

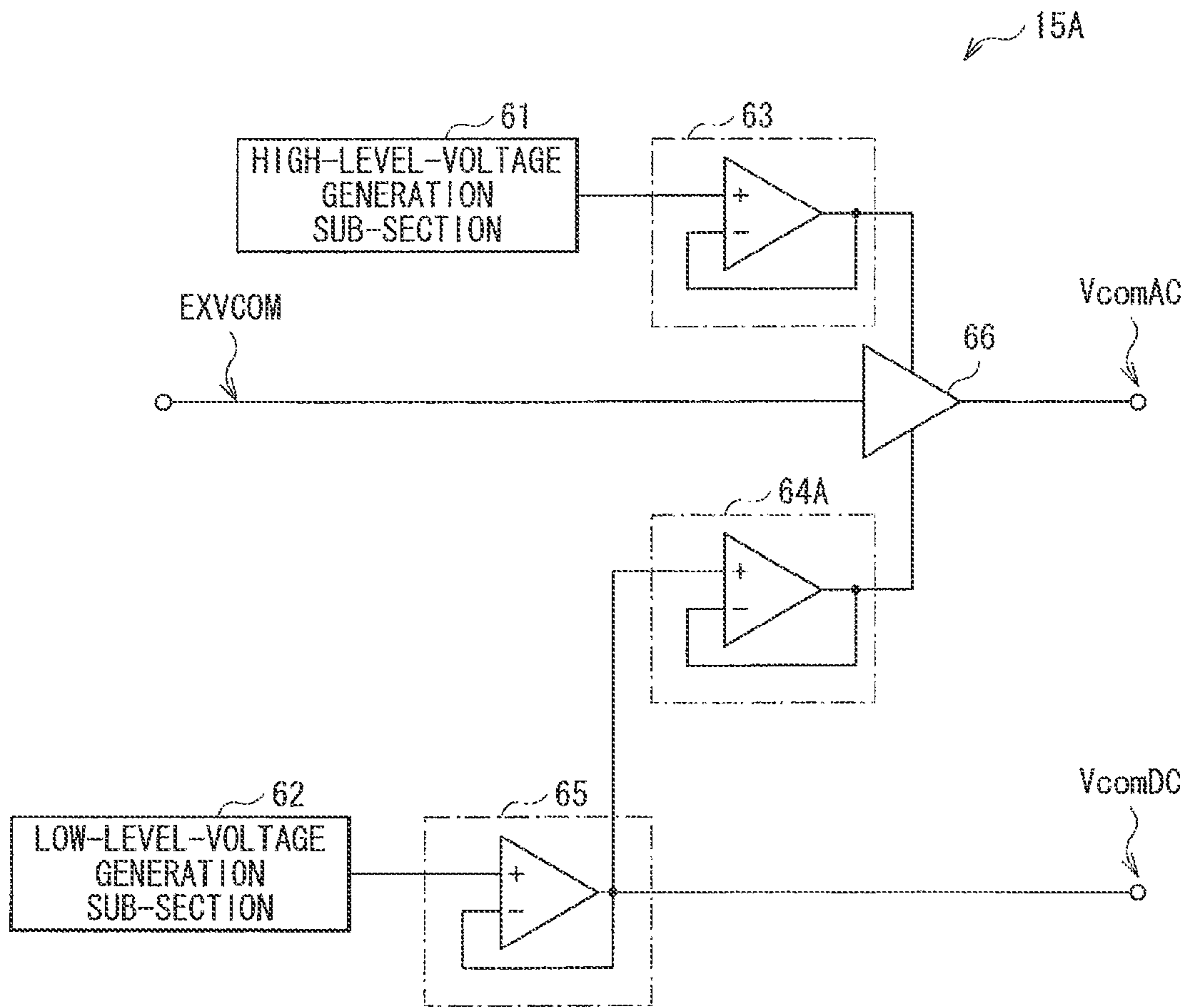


FIG. 18

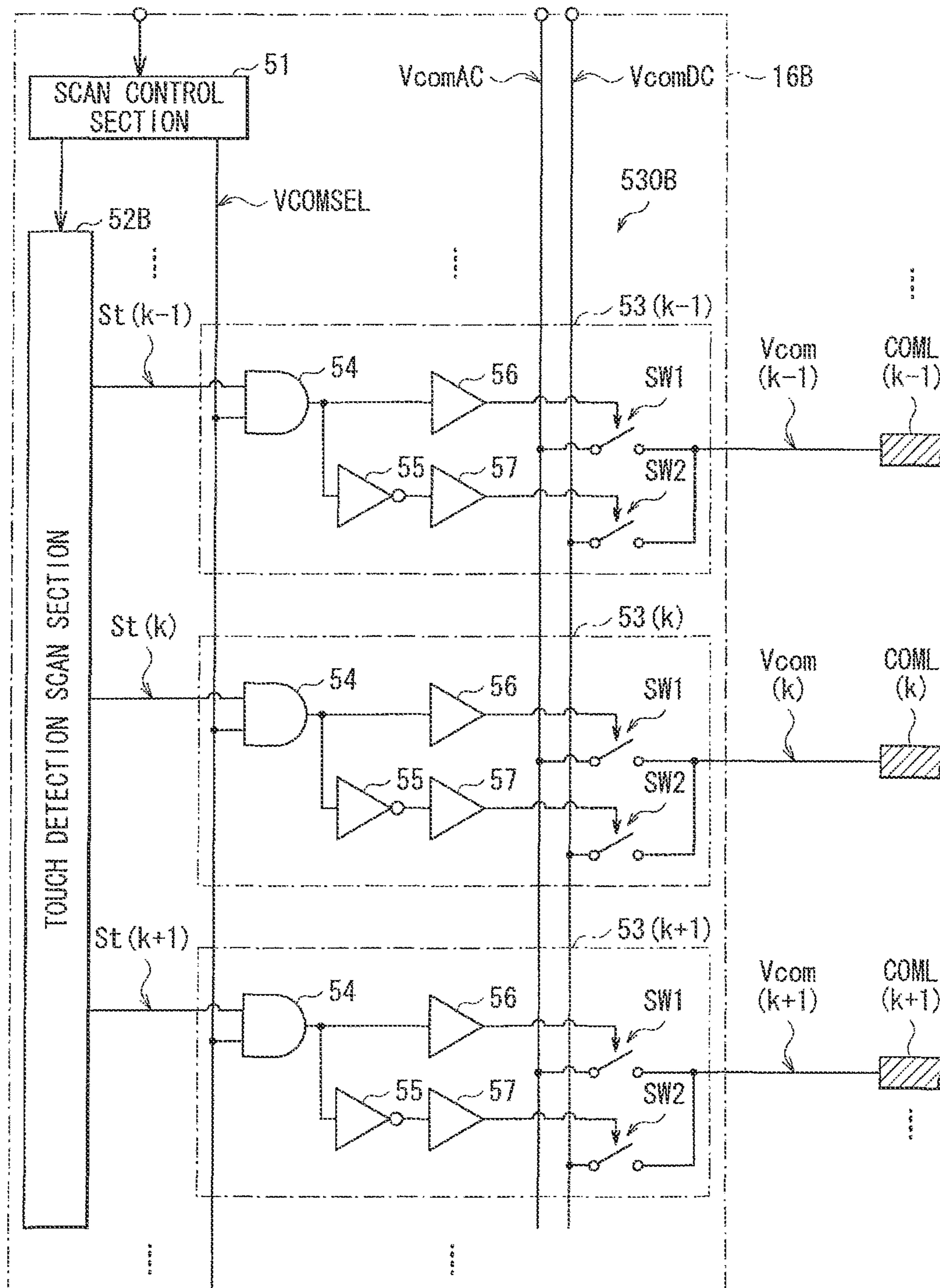


FIG. 19

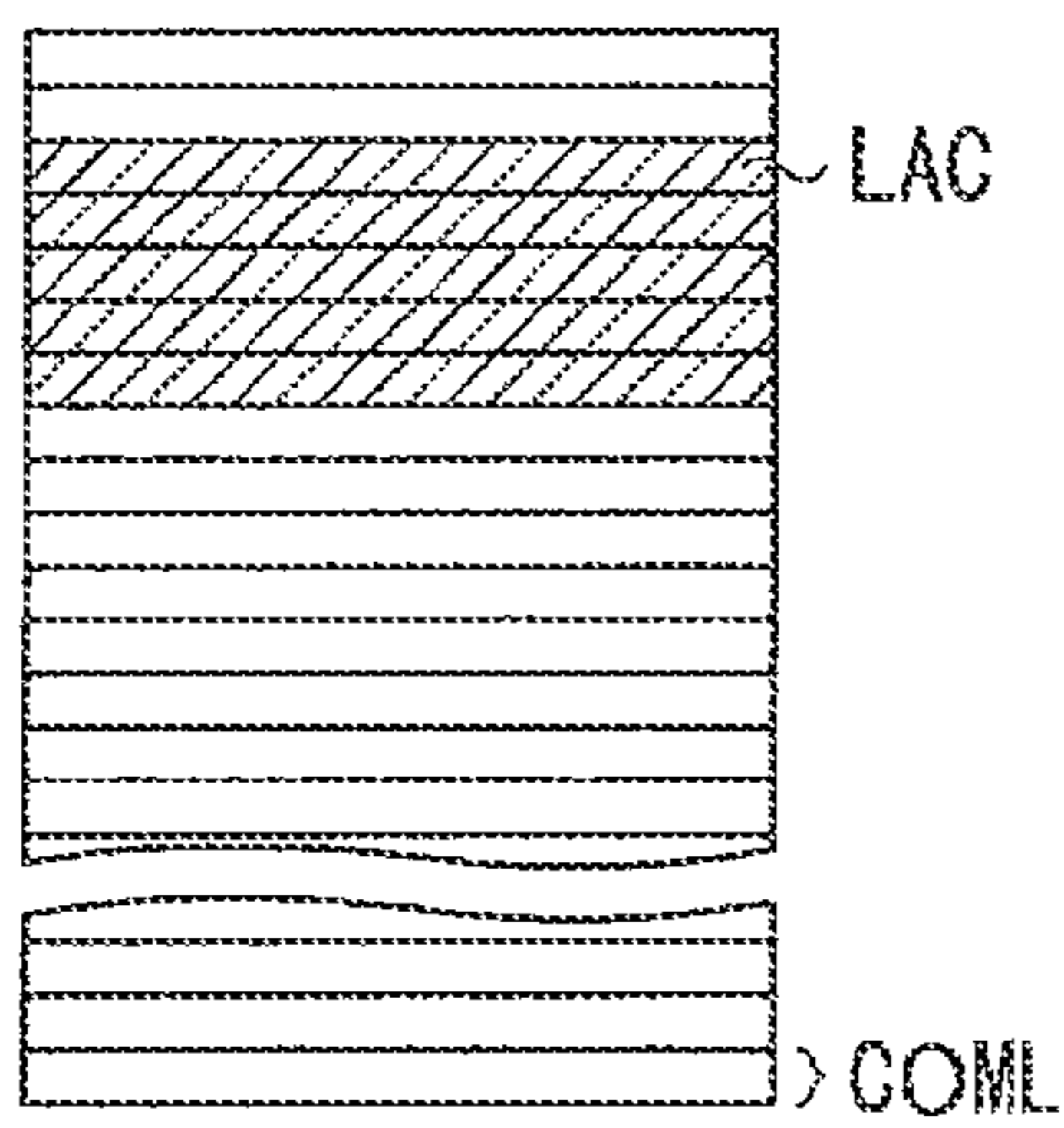


FIG. 20A

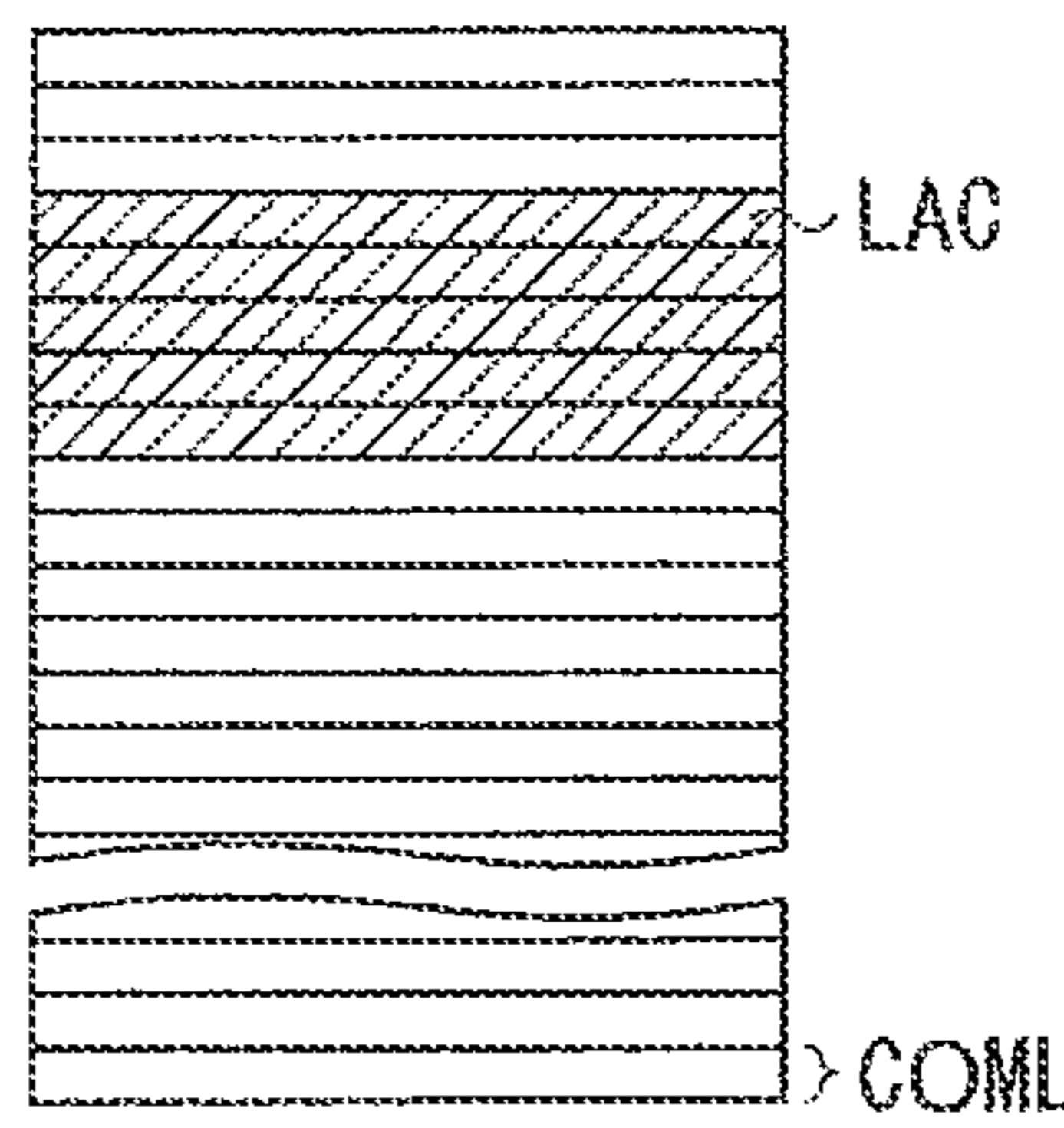


FIG. 20B

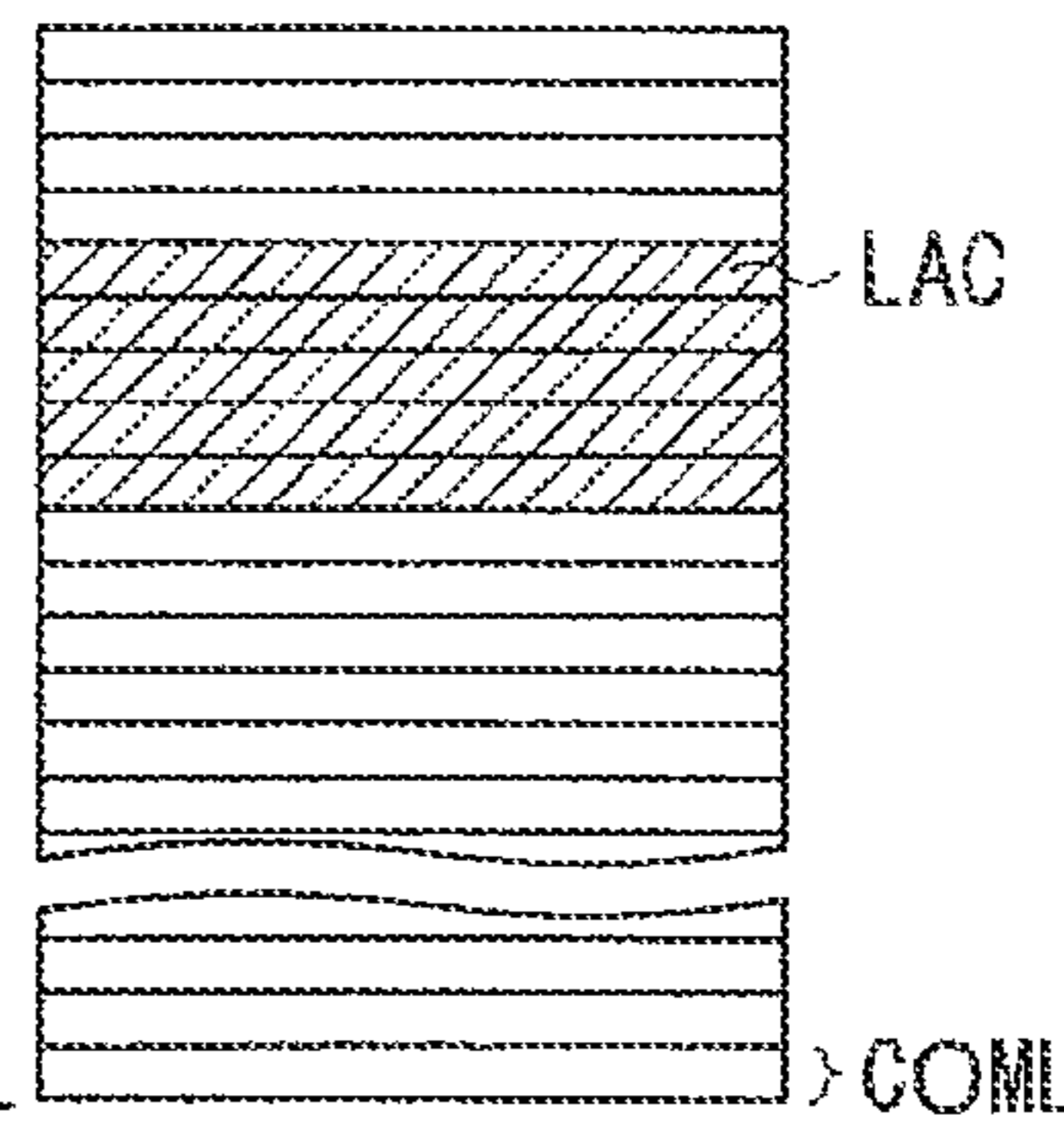


FIG. 20C

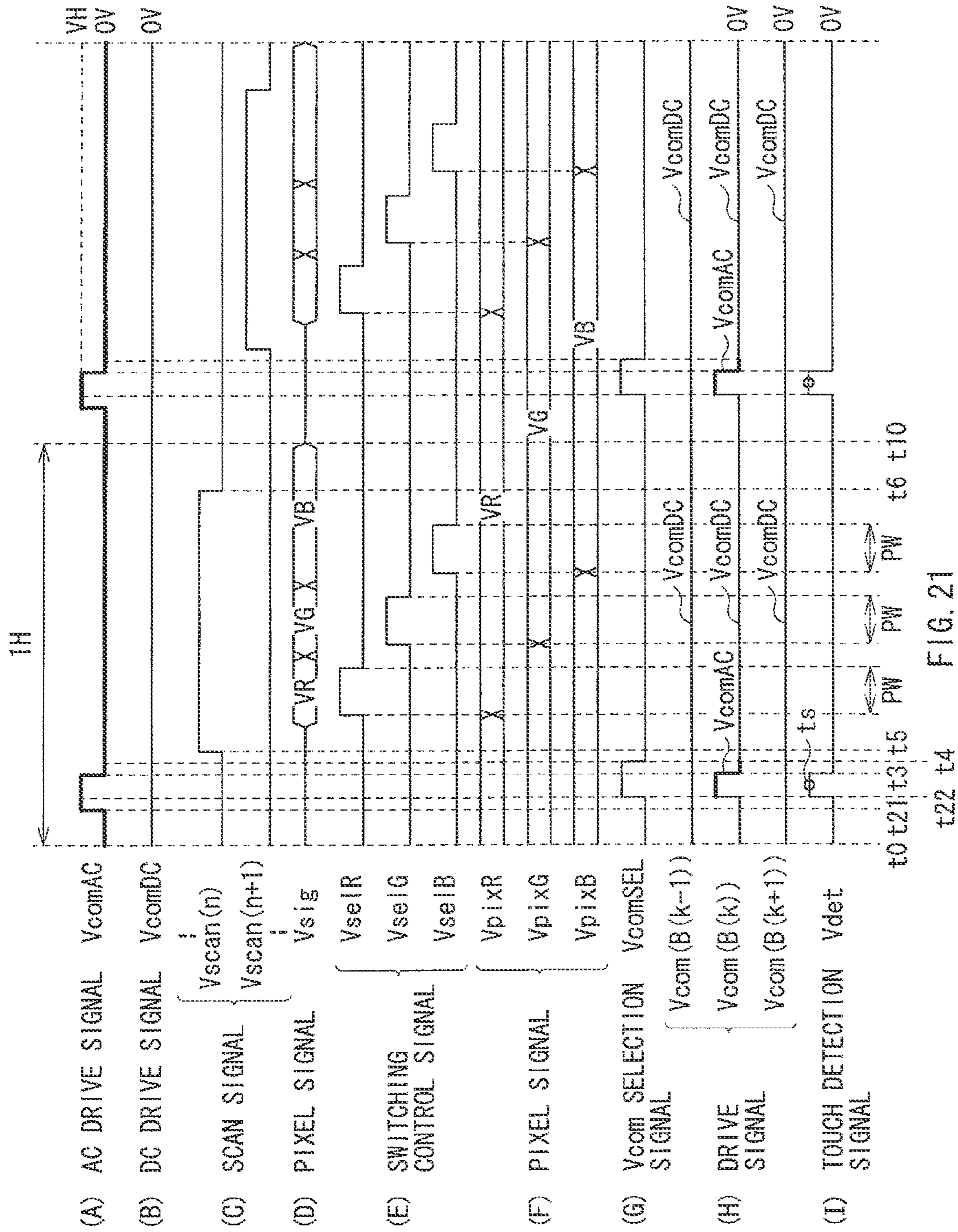


FIG. 21

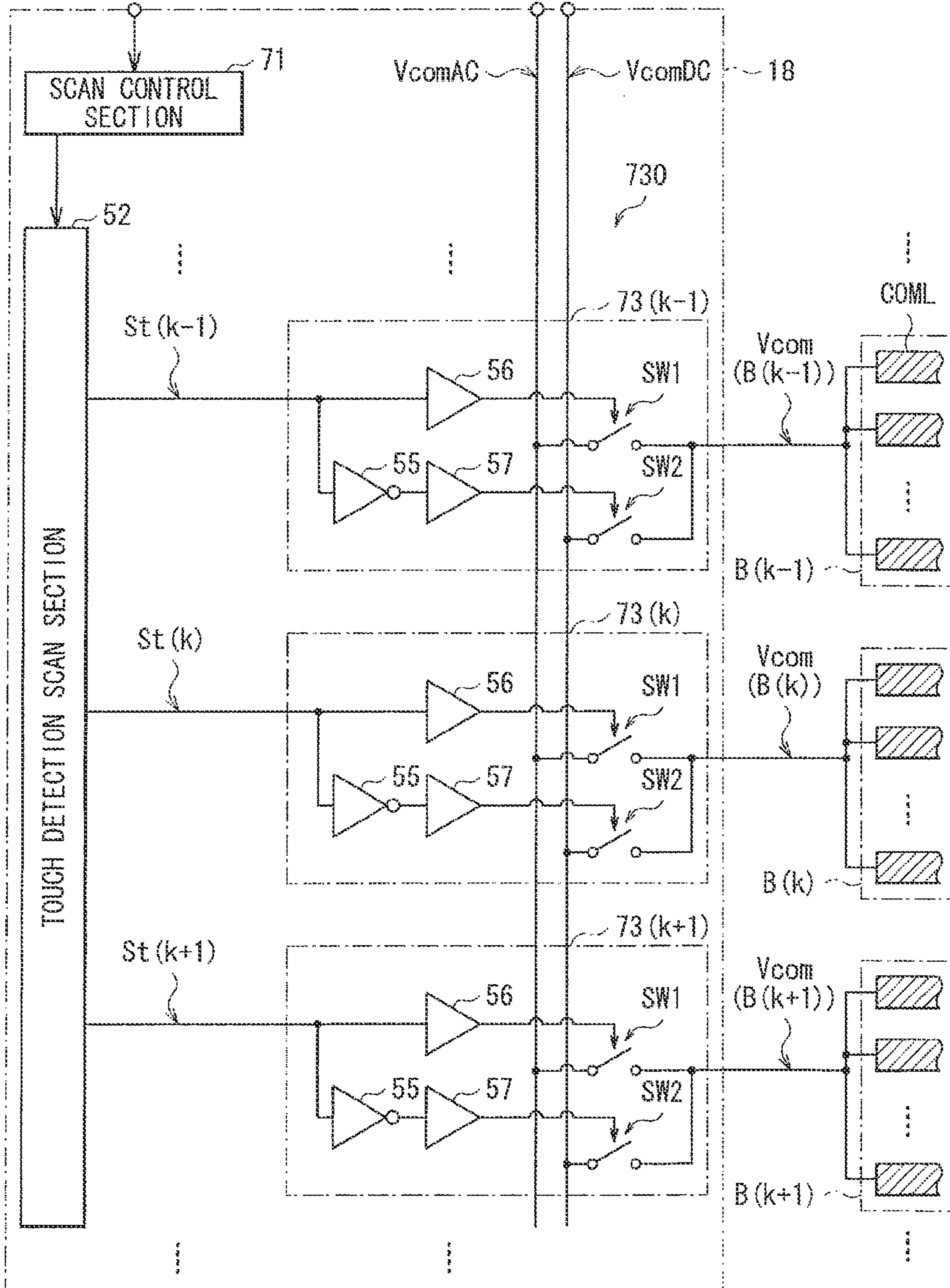


FIG. 22

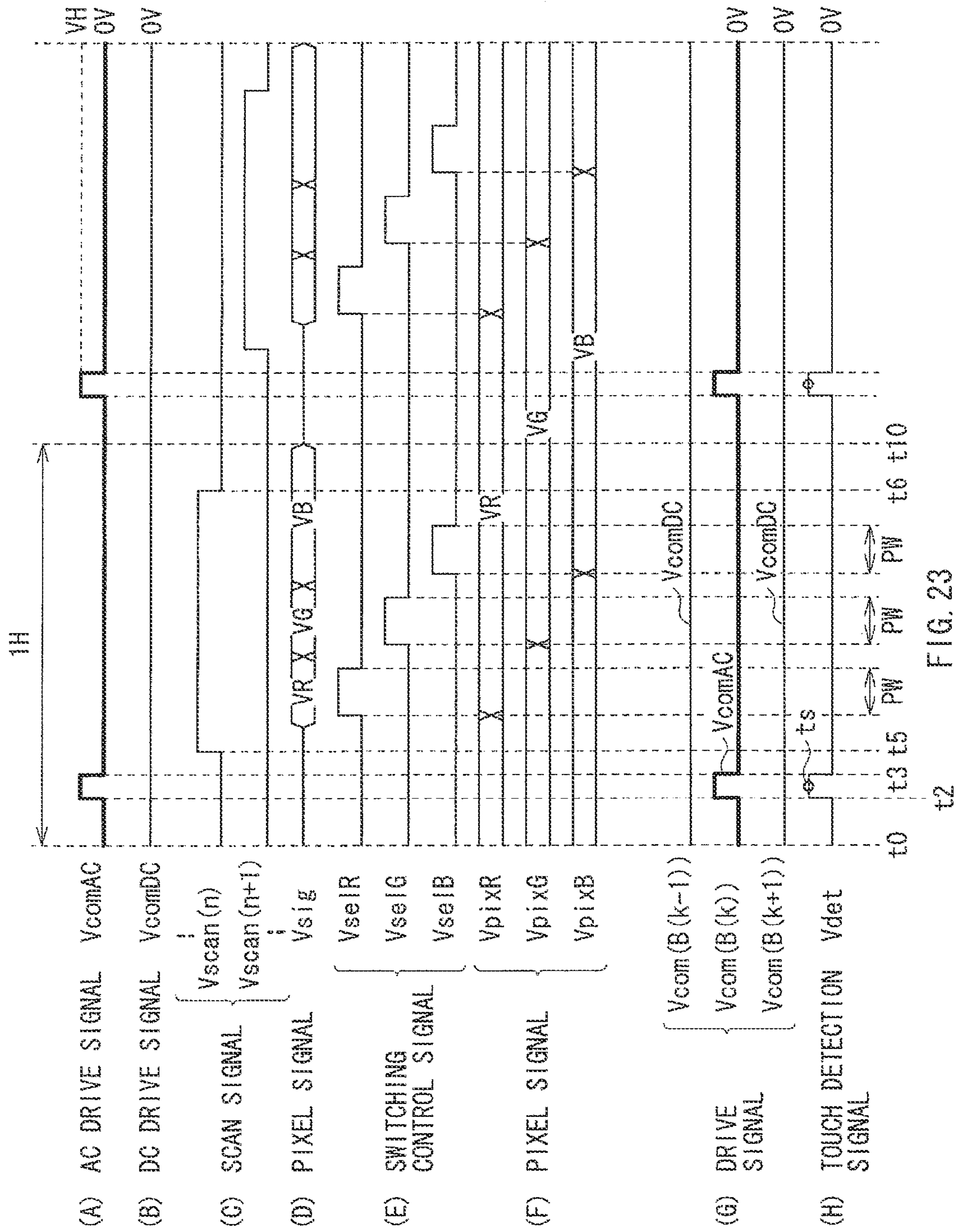


FIG. 23

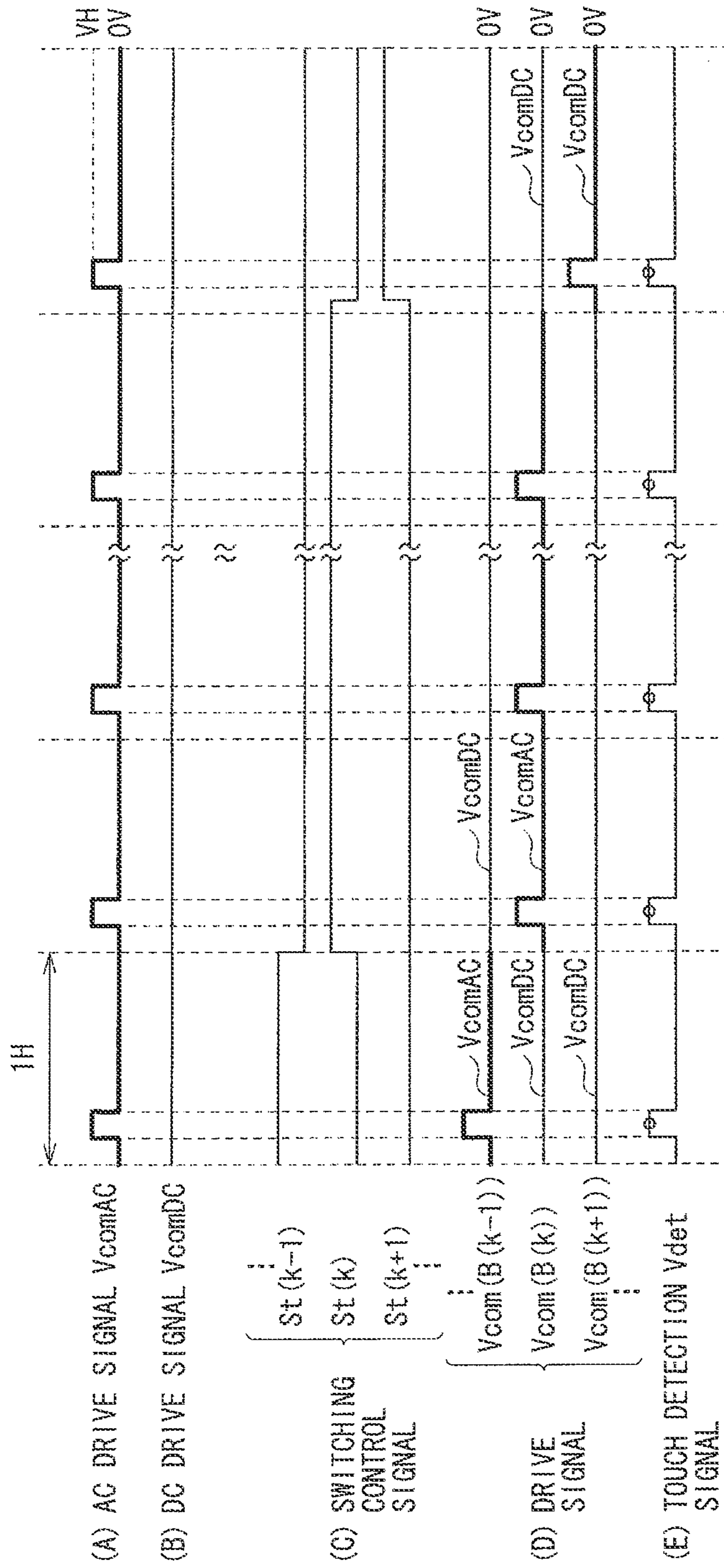


FIG. 24

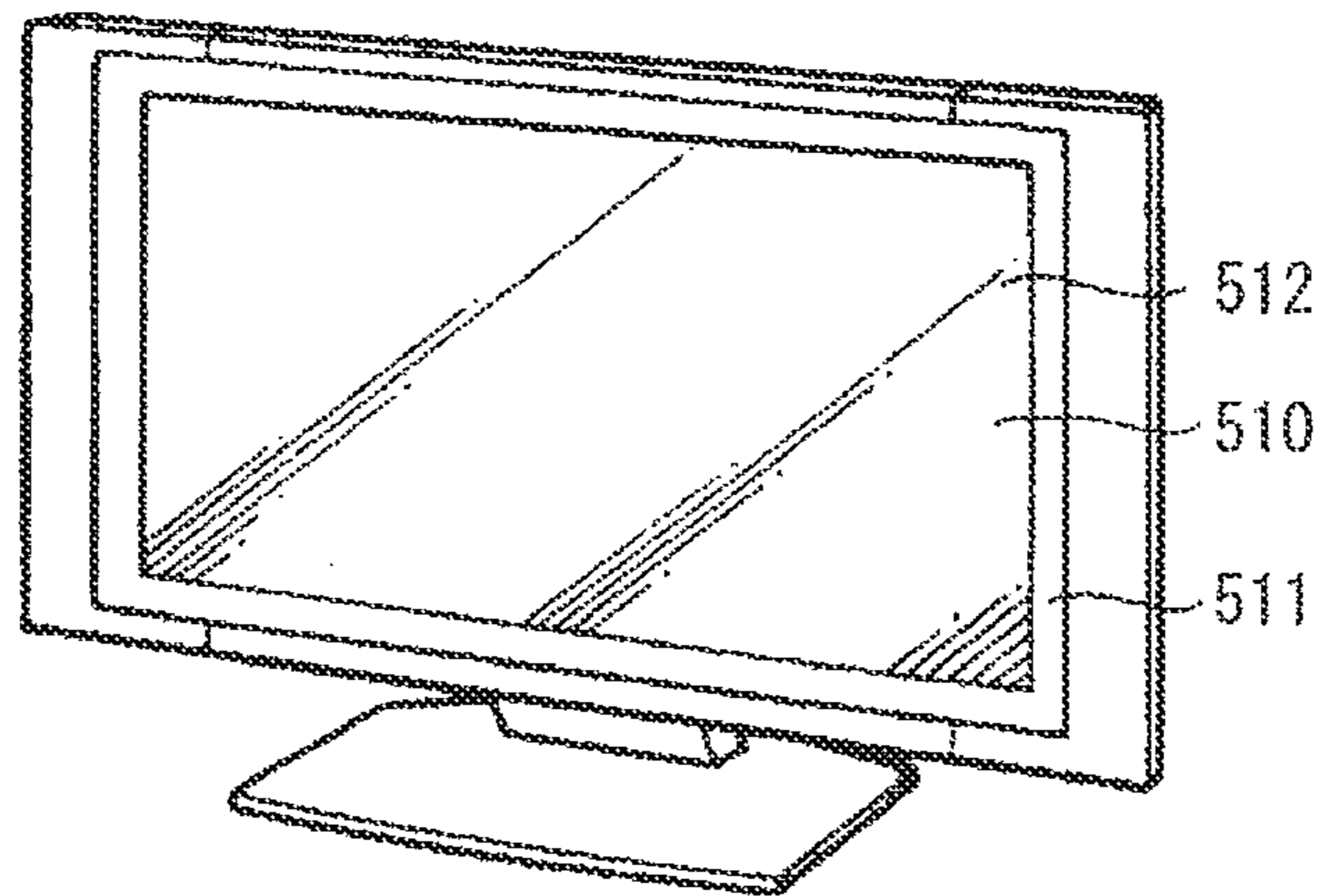


FIG. 25

FIG. 26A

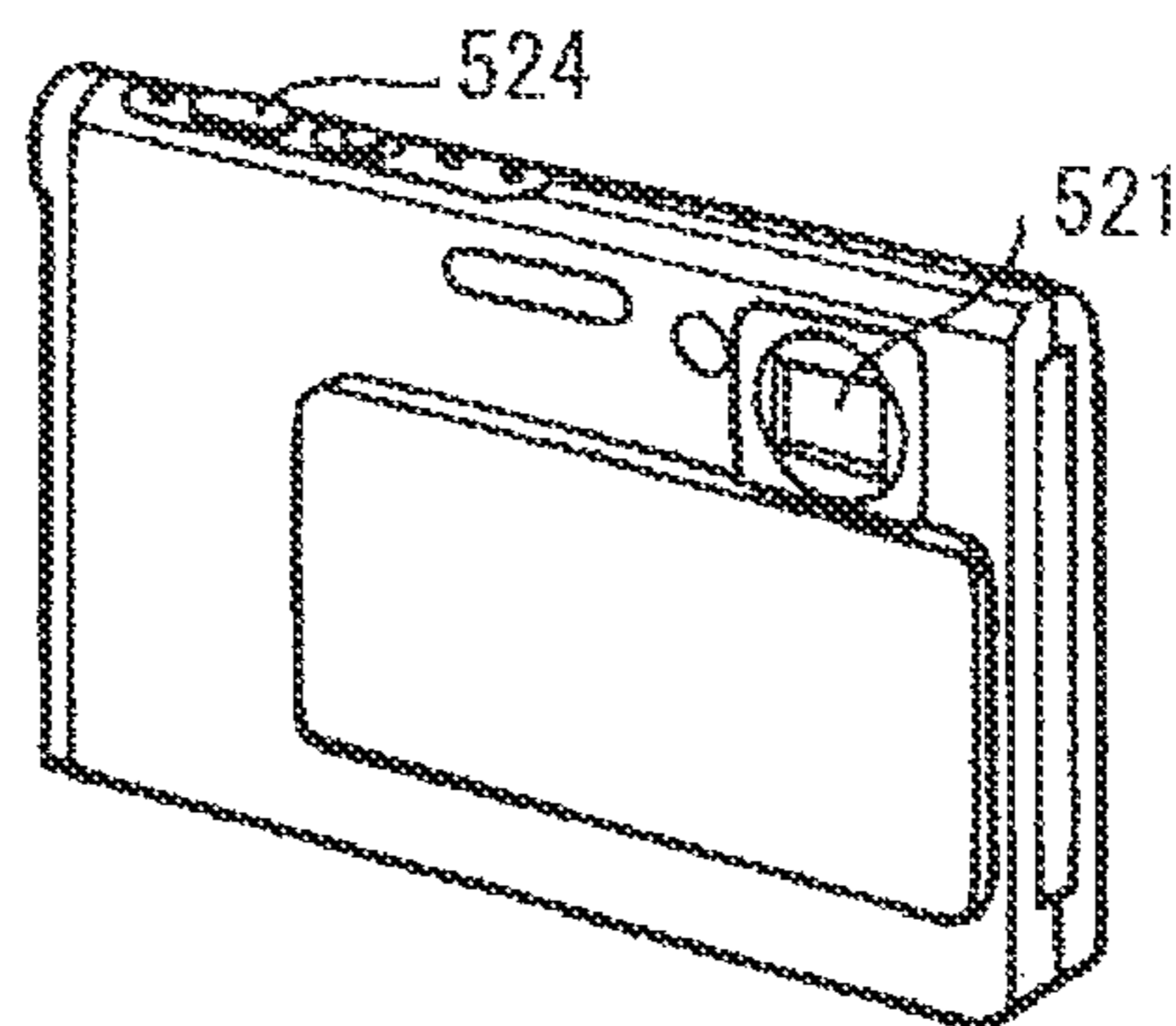
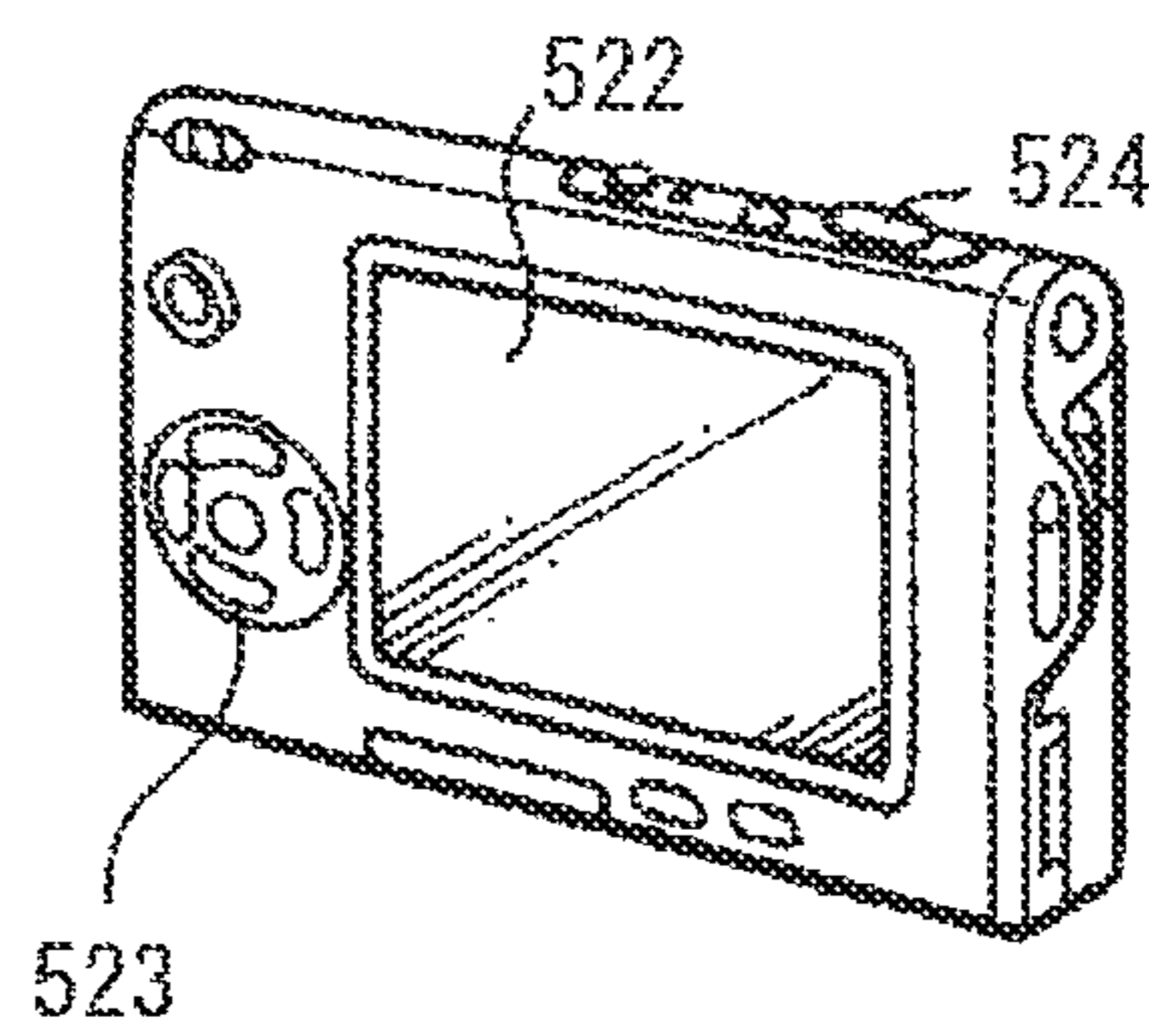


FIG. 26B



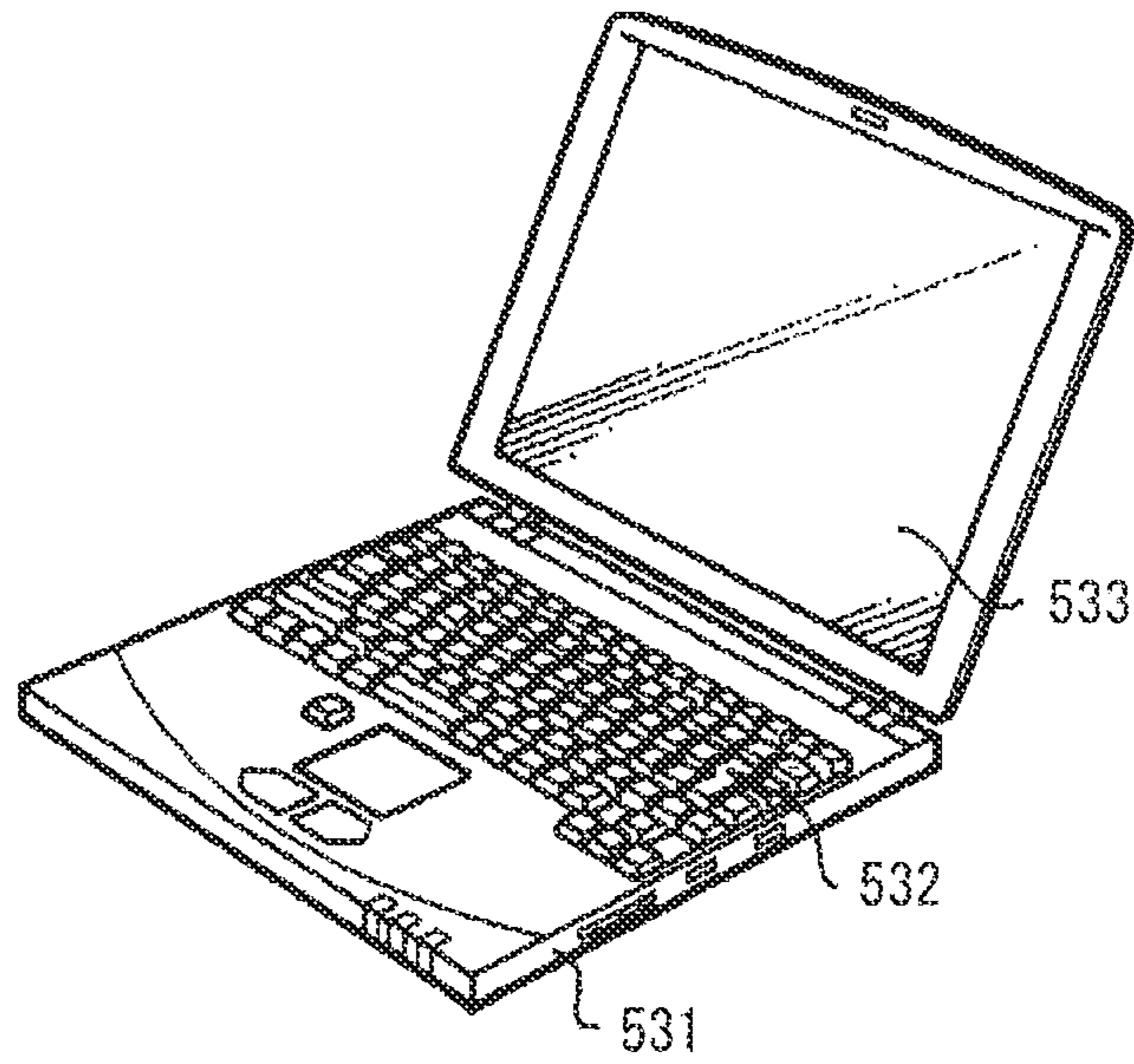


FIG. 27

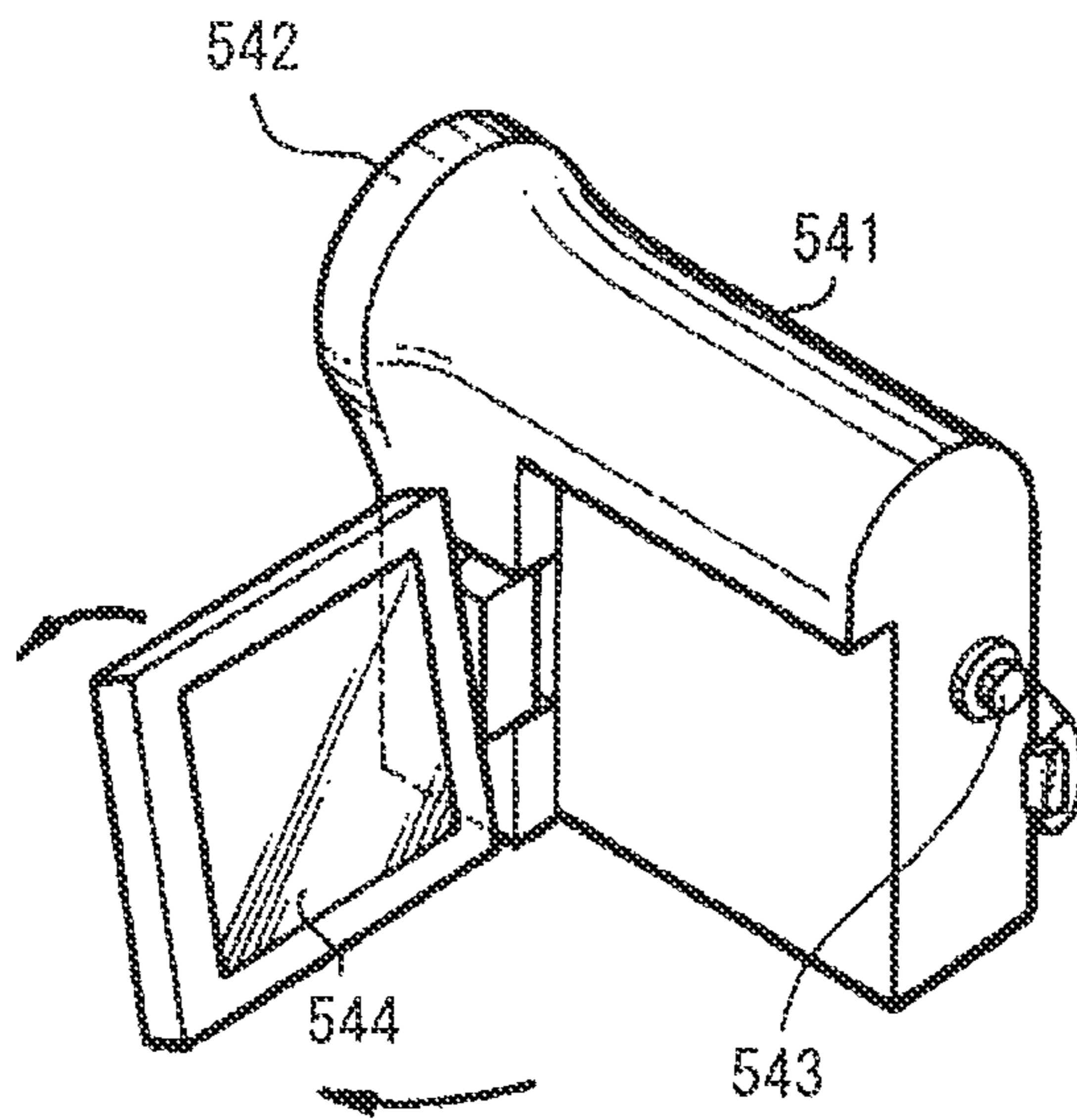


FIG. 28

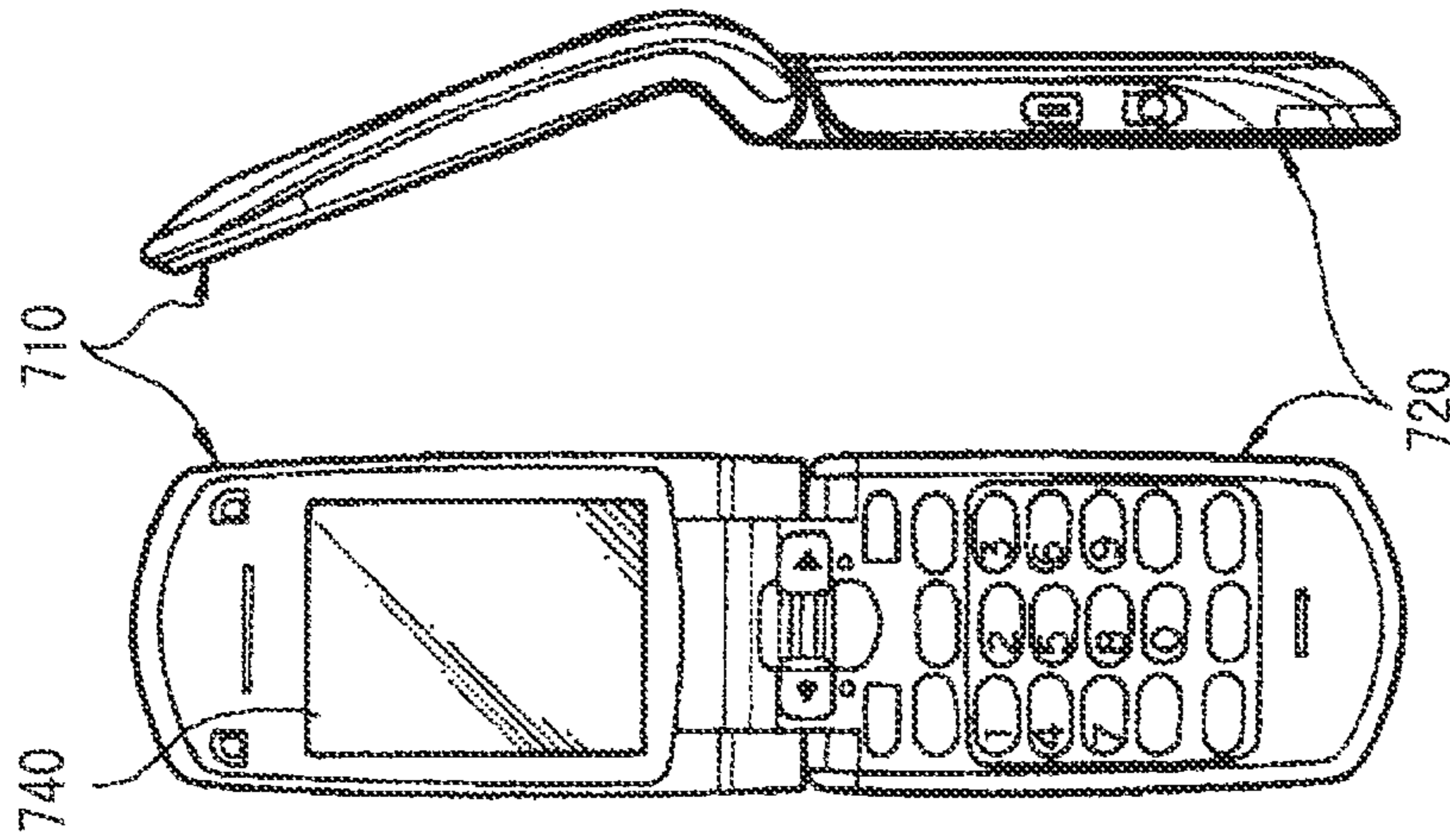


FIG. 29A

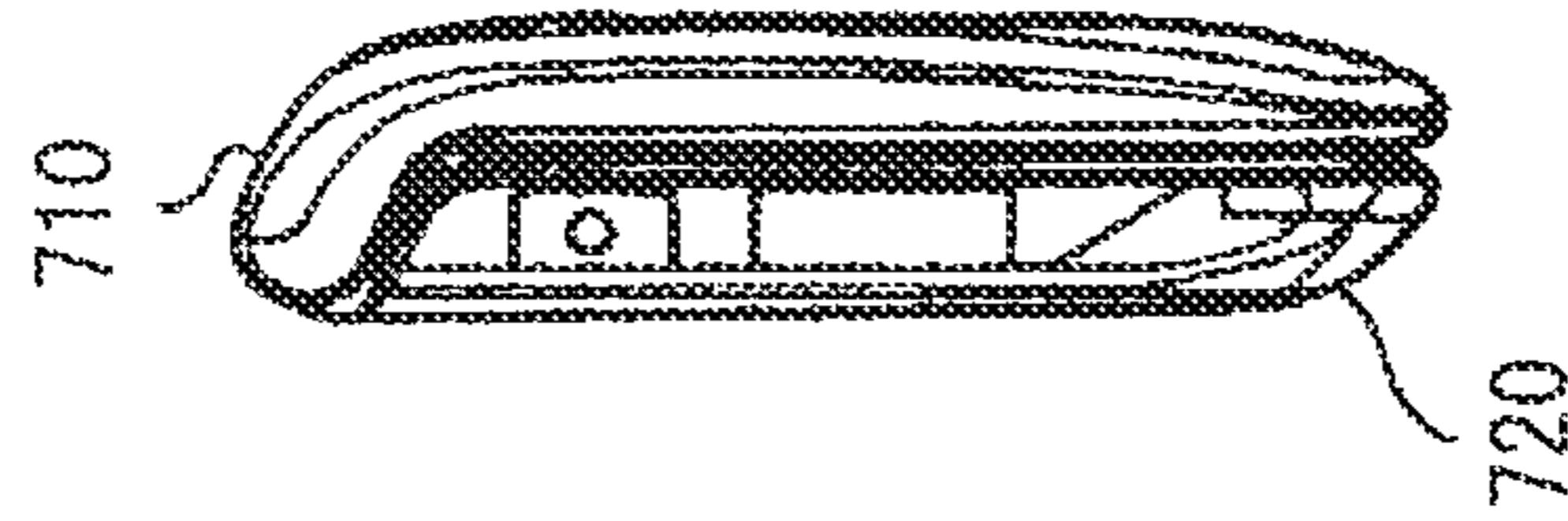


FIG. 29D

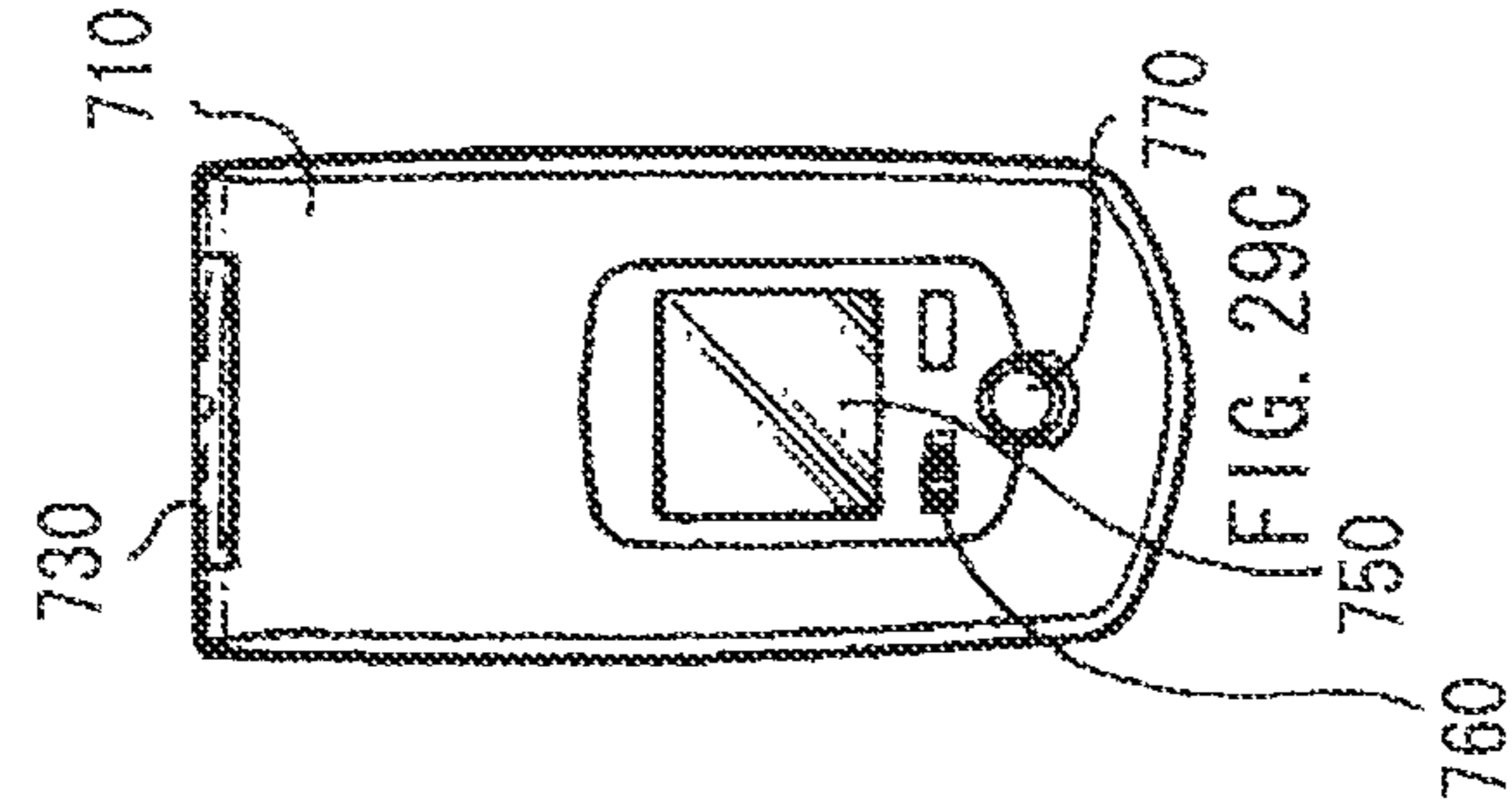


FIG. 29C

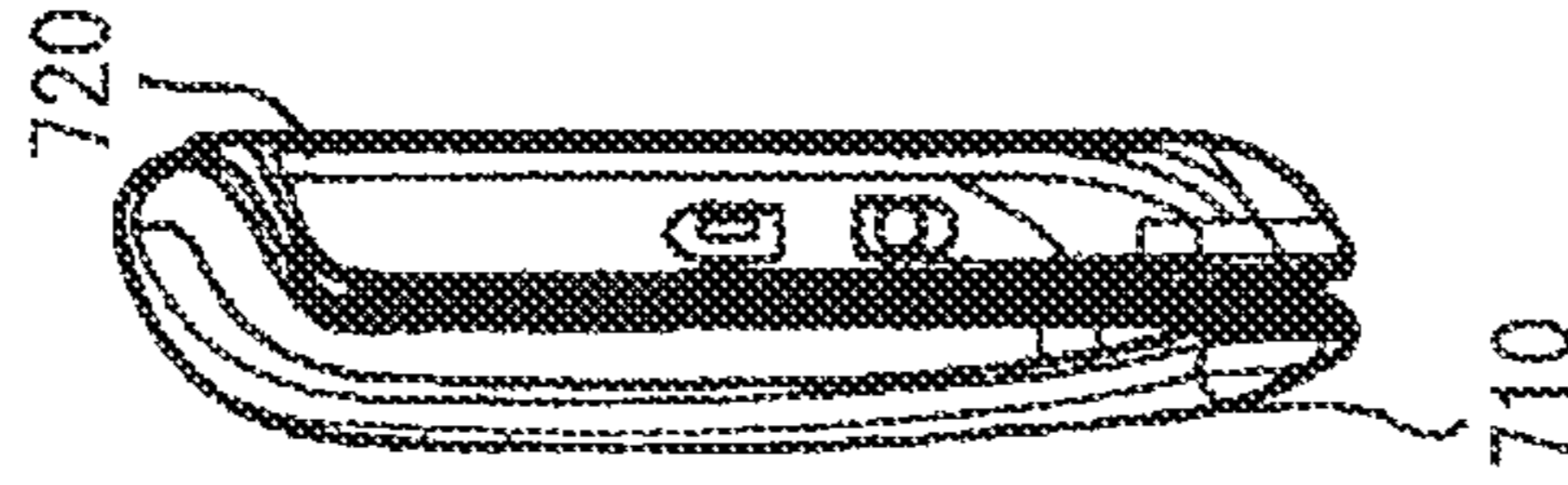


FIG. 29E

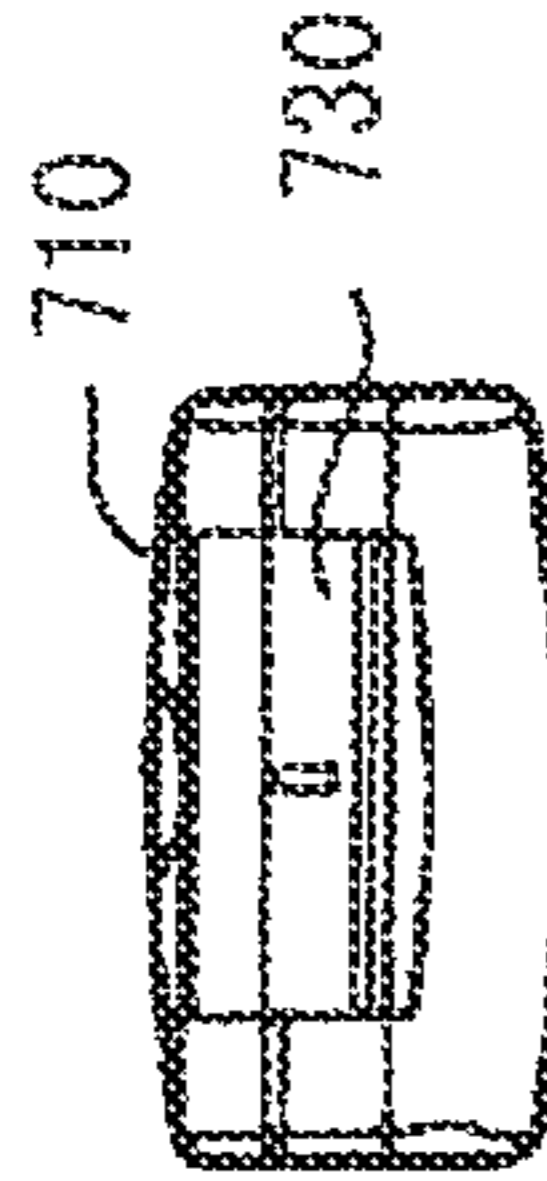


FIG. 29F

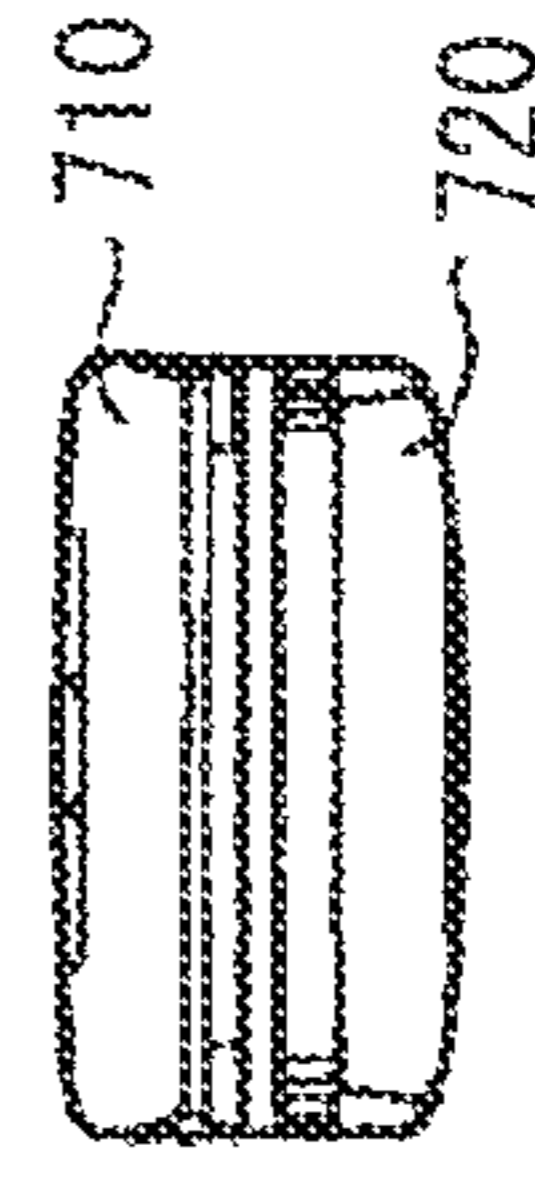


FIG. 29G

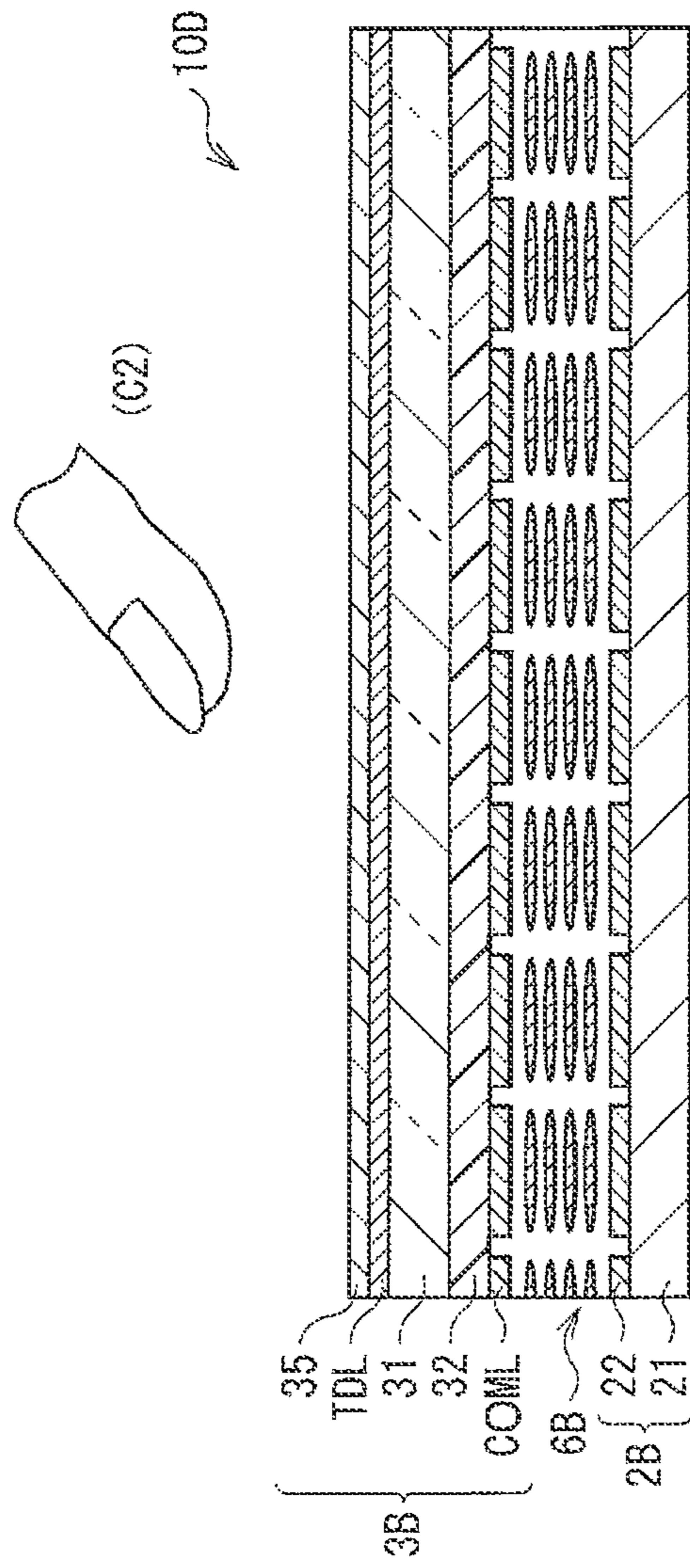


FIG. 30

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**DISPLAY PANEL WITH TOUCH DETECTION
FUNCTION, METHOD OF DRIVING THE
SAME, DRIVING CIRCUIT, AND
ELECTRONIC UNIT**

CROSS REFERENCES TO RELATED
APPLICATIONS

This is a Continuation application of the patent application Ser. No. 14/306,633, filed Jun. 17, 2014, which is a Continuation application of the patent application Ser. No. 13/414,363, filed Mar. 7, 2012, now U.S. Pat. No. 8,791,916, issued on Jul. 29, 2014, which claims priority from Japanese Patent Application No. 2011-089429, filed Apr. 13, 2011, and Japanese Patent Application No. 2011-242797, filed Nov. 4, 2011, the entire contents of which being incorporated herein by reference.

BACKGROUND

The present disclosure relates to a display panel with a touch detection function of detecting a touch event due to an external proximity object, a method of driving the same, a driving circuit, and an electronic unit having the display panel with a touch detection function.

Recently, a display panel has been notified, where a touch detection device, a so-called touch panel, is mounted on a display unit such as a liquid crystal display unit, or the touch panel is integrated with the display unit, and various button images and the like are displayed on the display unit for inputting information, instead of typical mechanical buttons. Such a display panel having the touch panel needs not have an input device such as a keyboard, a mouse, and a keypad and therefore tends to be expansively used not only for computers but also for handheld information terminals such as mobile phones.

A type of the touch panel includes several types such as an optical type and a resistant type. In particular, a capacitance-type touch panel has been promising as a device allowing low power consumption with a relatively simple structure. For example, Japanese Unexamined Patent Application Publication No. 2009-244958 (JP-A-2009-244958) proposes a so-called in-cell-type display panel with a touch detection function, where a common-electrode originally provided for display of a display unit is used also as one of a pair of electrodes for a touch sensor, and the other electrode (touch detection electrode) is disposed to intersect the common electrode. In addition, several propositions have been made on a so-called on-cell-type display panel with a touch detection function, in which a touch panel is provided on a display surface of a display unit.

SUMMARY

In the display panel with a touch detection function, since a display function is integrated with the touch detection function, for example, display operation may be affected by operation for touch detection. However, JP-A-2009-244958 has no description on such influence and measures against the influence.

It is desirable to provide a display panel with a touch detection function, in which display operation is less affected by touch detection operation, a method of driving the display panel with a touch detection function, a driving circuit, and an electronic unit having the display panel with a touch detection function.

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A display panel with a touch detection function according to an embodiment of the disclosure includes one or more display elements; one or more drive electrodes; one or more touch detection electrodes; and a drive section. The drive section selectively applies a DC drive signal or an AC drive signal to the drive electrodes.

A method of driving the display panel with a touch detection function according to an embodiment of the disclosure includes driving one or more display elements for display, and selectively applying a DC drive signal or an AC drive signal to the one or more drive electrodes.

A drive circuit according to an embodiment of the disclosure includes a display drive section and a touch detection drive section. The display drive section drives one or more display elements. The touch detection drive section selectively applies a DC drive signal or an AC drive signal to one or more drive electrodes.

An electronic unit according to an embodiment of the disclosure includes a display panel with a touch detection function, and a control section controlling operation using the display panel with a touch detection function. The display panel with a touch detection function includes one or more display elements, one or more drive electrodes, one or more touch detection electrodes, and a drive section selectively applying a DC drive signal or an AC drive signal to the drive electrodes. Such an electronic unit includes, for example, a television apparatus, a digital camera, a personal computer, a video camera, and a mobile terminal device such as a mobile phone.

In the display panel with a touch detection function and the method of driving the display panel with a touch detection function, the drive circuit, and the electronic unit according to the embodiments of the disclosure, the display elements are driven for display, a drive signal is applied to the drive electrodes, and the touch detection electrodes output a signal corresponding to the drive signal. At that time, one of the DC drive signal and the AC drive signal is selectively applied as the drive signal to the drive electrodes.

According to the display panel with a touch detection function and the method of driving the display panel with a touch detection function, the drive circuit, and the electronic unit according to the embodiments of the disclosure, since the DC drive signal or the AC drive signal is selectively applied to the drive electrodes, display operation is less affected by touch detection operation.

It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the technology as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the disclosure, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments and, together with the specification, serve to explain the principles of the technology.

FIG. 1 is a diagram for explaining a basic principle of a touch detection process of a display panel with a touch detection function according to embodiments of the disclosure, showing a state where a finger is not in contact with or not in proximity to the display panel.

FIG. 2 is a diagram for explaining the basic principle of the touch detection process of the display panel with a touch detection function according to the embodiments of the disclosure, showing a state where a finger is in contact with or in proximity to the display panel.

FIG. 3 is a diagram for explaining the basic principle of the touch detection process of the display panel with a touch detection function according to the embodiments of the disclosure, showing exemplary waveforms of a drive signal and a touch detection signal.

FIG. 4 is a block diagram illustrating an exemplary configuration of a display panel with a touch detection function according to a first embodiment of the disclosure.

FIG. 5 is a block diagram illustrating an exemplary configuration of a selection switch section shown in FIG. 4.

FIG. 6 is a sectional diagram illustrating a schematic sectional structure of a display device with a touch detection function shown in FIG. 4.

FIG. 7 is a circuit diagram illustrating a pixel arrangement in the display device with a touch detection function shown in FIG. 4.

FIG. 8 is a perspective diagram illustrating exemplary configurations of drive electrodes and touch detection electrodes of the display device with a touch detection function shown in FIG. 4.

FIGS. 9A to 9C are schematic diagrams illustrating an exemplary operation of touch detection scan of the display panel with a touch detection function shown in FIG. 4.

FIG. 10 is a schematic diagram illustrating exemplary operations of display scan and touch detection scan of the display panel with a touch detection function shown in FIG. 4.

FIG. 11 is a block diagram illustrating an exemplary configuration of a drive signal generation section shown in FIG. 4.

FIG. 12 is a block diagram illustrating an exemplary configuration of a drive electrode driver according to the first embodiment.

FIG. 13 is a timing waveform chart illustrating an exemplary operation of the display panel with a touch detection function according to the first embodiment.

FIG. 14 is a timing waveform chart illustrating an exemplary touch detection operation of the display panel with a touch detection function according to the first embodiment.

FIG. 15 is a block diagram illustrating an exemplary configuration of a drive signal generation section according to a comparative example.

FIG. 16 is a block diagram illustrating an exemplary configuration of a drive electrode driver according to the comparative example.

FIG. 17 is a timing waveform chart illustrating an exemplary operation of a display panel with a touch detection function according to the comparative example.

FIG. 18 is a block diagram illustrating an exemplary configuration of a drive signal generation section according to a modification of the embodiment.

FIG. 19 is a block diagram illustrating an exemplary configuration of a drive electrode driver according to another modification of the embodiment.

FIGS. 20A to 20C are schematic diagrams illustrating an exemplary operation of touch detection scan according to a still another modification of the embodiment.

FIG. 21 is a timing waveform chart illustrating an exemplary operation of a display panel with a touch detection function according to a still another modification of the embodiment.

FIG. 22 is a block diagram illustrating an exemplary configuration of a drive electrode driver according to a second embodiment.

FIG. 23 is a timing waveform chart illustrating an exemplary operation of the display panel with a touch detection function according to the second embodiment.

FIG. 24 is a timing waveform chart illustrating an exemplary touch detection operation of the display panel with a touch detection function according to the second embodiment.

FIG. 25 is a perspective diagram illustrating an appearance configuration of an application example 1, among display panels with a touch detection function applied with the embodiments.

FIGS. 26A and 26B are perspective diagrams illustrating an appearance configuration of an application example 2.

FIG. 27 is a perspective diagram illustrating an appearance configuration of an application example 3.

FIG. 28 is a perspective diagram illustrating an appearance configuration of an application example 4.

FIGS. 29A to 29G are front diagrams, side diagrams, a top diagram, and a bottom diagram illustrating an appearance configuration of an application example 5.

FIG. 30 is a sectional diagram illustrating a schematic sectional structure of a display device with a touch detection function according to a modification.

DETAILED DESCRIPTION

Hereinafter, embodiments of the disclosure will be described in detail with reference to the accompanying drawings. It is to be noted that description is made in the following order.

1. Basic Principle of Capacitance-Type Touch Detection
2. First Embodiment
3. Second Embodiment
4. Application Examples

[1. Basic Principle of Capacitance-Type Touch Detection]

First, a basic principle of touch detection of a display panel with a touch detection function according to embodiments of the disclosure is described with reference to FIGS. 1 to 3. This touch detection process is embodied as a capacitance-type touch sensor. In the capacitance-type touch sensor, for example, a pair of electrodes (drive electrode E1 and touch detection electrode E2) disposed to face each other with a dielectric body D in between are used to configure a capacitance element, as illustrated in (A) of FIG. 1. Such a structure is expressed as an equivalent circuit illustrated in (B) of FIG. 1. The drive electrode E1, the touch detection electrode E2, and the dielectric body D define a capacitance element C1. One end of the capacitance element C1 is connected to an AC signal source (drive signal source) S, and the other end P is grounded through a resistor R and connected to a voltage detector (a touch detection circuit) DET. After an AC rectangular wave Sg ((B) of FIG. 3) having a predetermined frequency (for example, approximately several kilohertz to several tens kilohertz) is applied from the AC signal source S to the drive electrode E1 (a first end of the capacitance element C1), an output waveform (a touch detection signal) Vdet, as illustrated in (A) of FIG. 3 is shown at the touch detection electrode E2 (a second end P of the capacitance element C1). It is to be noted that the AC rectangular wave Sg corresponds to an AC drive signal VcomAC described below.

In a state where a finger is not in contact with (or not in proximity to) the display panel, current I0 corresponding to a capacitance value of the capacitance element C1 flows in response to charge and discharge with respect to the capacitance element C1 as illustrated in FIG. 1. Here, a potential waveform at the second end P of the capacitance element C1 is, for example, as shown by a waveform V0 in (A) of FIG. 3, which is detected by the voltage detector DET.

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On the other hand, in a state where a finger is in contact with (or in proximity to) the display panel, a capacitance element C2 is formed by a finger and is added in series to the capacitance element C1 as illustrated in FIG. 2. In this state, a current I1 and a current I2 flow in response to charge and discharge of the capacitance elements C1 and C2, respectively. Here, a potential waveform at the second end P of the capacitance element C1 is, for example, as shown by a waveform V1 in (A) of FIG. 3, which is detected by the voltage detector DET. Here, electric potential of the point P corresponds to a divided potential determined by the values of the currents I1 and I2 flowing through the respective capacitance elements C1 and C2. The waveform V1, therefore, has a small value compared with the waveform V0 in the non-contact state. The voltage detector DET compares a detected voltage with a predetermined threshold voltage Vth. If the detected voltage is equal to or higher than the threshold voltage, the voltage detector DET determines that no contact occurs. If the detected voltage is lower than the threshold voltage, the voltage detector DET determines that some contact occurs. In this way, touch detection is performed.

[2. First Embodiment]

[Exemplary Configuration]

(Exemplary Overall Configuration)

FIG. 4 illustrates an exemplary configuration of a display panel with a touch detection function 1 according to a first embodiment. The display panel includes liquid crystal display elements as display elements, and is a so-called in-cell type display panel, in which a liquid crystal display device configured of the liquid crystal display elements is integrated with a capacitance-type touch detection device.

The display panel with a touch detection function 1 includes a control section 11, a gate driver 12, a source driver 13, a selection switch section 14, a drive signal generation section 15, a drive electrode driver 16, a display device with a touch detection function 10, and a touch detection section 40.

The control section 11 is a circuit that supplies a control signal to each of the gate driver 12, the source driver 13, the drive signal generation section 15, the drive electrode driver 16, and the touch detection section 40 based on a video signal Vdisp supplied from the outside, and controls the components to operate in synchronization with one another.

The gate driver 12 has a function of sequentially selecting one horizontal line as a display drive object in the display device with a touch detection function 10 based on the control signal supplied from the control section 11. In detail, the gate driver 12 generates a scan signal Vscan based on the control signal supplied from the control section 11, and applies the scan signal Vscan to a gate of a TFT element Tr of each pixel Pix through a scan signal line GCL to sequentially select one row (one horizontal line) as a display drive object of pixels Pix provided in a matrix in a liquid crystal display device 20 of the display device with a touch detection function 10.

The source driver 13 generates and outputs a pixel signal Vsig based on a video signal and a source driver control signal supplied from the control section 11. In detail, the source driver 13 generates the pixel signal Vsig, in which pixel signals Vpix for a plurality of (here, three) sub-pixels SPix of the liquid crystal display device 20 of the display device with a touch detection function 10 are time-divisionally multiplexed, from a video signal corresponding to one horizontal line, and supplies the pixel signal Vsig to the selection switch section 14, as described below. In addition, the source driver 13 generates a switching control signal

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Vsel (VselR, VselG, and VselB) necessary for demultiplexing the pixel signals Vpix multiplexed into the pixel signal Vsig, and supplies the switching control signal Vsel together with the pixel signal Vsig to the selection switch section 14.

It is to be noted that such multiplexing is performed to reduce the number of wirings between the source driver 13 and the selection switch section 14.

The selection switch section 14 demultiplexes the pixel signals Vpix, which have been time-divisionally multiplexed into the pixel signal Vsig, based on the pixel signal Vsig and the switching control signal Vsel supplied from the source driver 13, and supplies the pixel signals Vpix to the liquid crystal display device 20 of the display device with a touch detection function 10.

FIG. 5 illustrates an exemplary configuration of the selection switch section 14. The selection switch section 14 has a plurality of switch groups 17. Each switch group 17 includes three switches SWR, SWG, and SWB herein, where respective first ends of the switches are connected to one another and supplied with a pixel signal Vsig from the source driver 13, and respective second ends thereof are connected to three sub-pixels SPix (R, G, and B) relevant to a pixel Pix through pixel signal lines SGL of the liquid crystal display device 20 of the display device with a touch detection function 10. The respective three switches SWR, SWG, and SWB are controlled to be on or off by the switching control signal Vsel (VselR, VselG, and VselB) supplied from the source driver 13. According to such a configuration, the selection switch section 14 sequentially changes the three switches SWR, SWG, and SWB in a time-divisional manner to be on in response to the switching control signal Vsel, thereby demultiplexing the pixel signals Vpix (VpixR, VpixG, and VpixB) from the multiplexed pixel signal Vsig. In addition, the selection switch section 14 supplies the respective pixel signals Vpix to the three sub-pixels SPix (R, G, and B).

The drive signal generation section 15 generates a drive signal Vcom based on a control signal supplied from the control section 11. In detail, the drive signal generation section 15 generates a DC drive signal VcomDC and generates an AC drive signal VcomAC based on a Vcom control signal EXVCOM (described below) supplied from the control section 11, and supplies the signals to the drive electrode driver 16, as described below. The DC drive signal VcomDC is a DC signal having a voltage of 0 V. The AC drive signal VcomAC has a pulse waveform having a low-level voltage of 0 V and a high-level voltage of VH.

The drive electrode driver 16 is a circuit that supplies the drive signal Vcom to drive electrodes COML (described below) of the display device with a touch detection function 10 based on a control signal supplied from the control section 11. In detail, the drive electrode driver 16 applies the AC drive signal VcomAC to the relevant drive electrodes COML in touch detection operation. At that time, the drive electrode driver 16 drives the drive electrodes COML by one block (drive electrode block B described below) including a predetermined number of drive electrodes COML at a time. In addition, the drive electrode driver 16 applies the DC drive signal VcomDC to the drive electrodes COML other than the drive electrodes COML relevant to the touch detection operation.

The display device with a touch detection function 10 is a display device in which a touch detection function is embedded. The display device with a touch detection function 10 includes the liquid crystal display device 20 and a touch detection device 30. The liquid crystal display device 20 performs sequential scan by one horizontal line basis for

performing display in response to scan signals V_{scan} supplied from the gate driver **12**, as described below. The touch detection device **30** operates on the basis of the above-described basic principle of the capacitance-type touch detection and outputs a touch detection signal V_{det} . The touch detection device **30** performs sequential scan in response to the AC drive signal V_{comAC} supplied from the drive electrode driver **16** to perform touch detection, as described below.

The touch detection section **40** detects presence of a touch event in the touch detection device **30** based on a touch detection control signal supplied from the control section **11** and the touch detection signal V_{det} supplied from the touch detection device **30** of the display device with a touch detection function **10**, and obtains the coordinates of a touch event in a touch detection region if the touch event is detected. The touch detection section **40** includes a low pass filter (LPF) section **42**, an A/D conversion section **43**, a signal processing section **44**, a coordinate extraction section **45**, and a detection timing control section **46**. The LPF section **42** is a low-pass analog filter that removes the high-frequency components (noise components) contained in the touch detection signal V_{det} supplied from the touch detection device **30**, and thus extracts and outputs the touch components. A resistance R for providing a DC potential (0 V) is connected between each of input terminals of the LPF section **42** and ground. It is to be noted that, for example, a switch may be provided in place of the resistance R such that the switch is turned on at a predetermined timing so as to provide the DC potential (0 V). The A/D conversion section **43** is a circuit that samples each of the analog signals output from the LPF section **42** at a timing in synchronization with the AC drive signal V_{comAC} , and converts the analog signals to digital signals. The signal processing section **44** is a logical circuit that detects presence of a touch event in the touch detection device **30** based on signals output from the A/D conversion section **43**. The coordinate extraction section **45** is a logical circuit that determines touch-panel coordinates of a touch event if signal processing section **44** detects a touch event. The detection timing control section **46** controls these circuits to operate in synchronization with one another.

(Display Device with Touch Detection Function **10**)

An exemplary configuration of the display device with a touch detection function **10** is now described in detail.

FIG. **6** illustrates an exemplary sectional structure of a major part of the display device with a touch detection function **10**. The display device with a touch detection function **10** includes a pixel substrate **2**, a counter substrate **3** disposed to face the pixel substrate **2**, and a liquid crystal layer **6** interposed between the pixel substrate **2** and the counter substrate **3**.

The pixel substrate **2** includes a TFT substrate **21** as a circuit substrate, the drive electrodes COML, and pixel electrodes **22**. The TFT substrate **21** functions as a circuit substrate on which various kinds of electrodes, wirings, thin film transistors (TFTs), and the like are provided. The TFT substrate **21** is configured of, for example, glass. The drive electrodes COML are provided on the TFT substrate **21**. The drive electrodes COML are electrodes for supplying the common voltage to a plurality of pixels Pix (described below). The drive electrodes COML function as a common drive electrode for liquid crystal display operation, and also function as the drive electrodes for touch detection operation. An insulating layer **23** is provided on the drive electrodes COML, and the pixel electrodes **22** are provided on the insulating layer **23**. The pixel electrodes **22** are translu-

cent electrodes for supplying the pixel signals for performing display. The drive electrodes COML and the pixel electrodes **22** include, for example, indium tin oxide (ITO).

The counter substrate **3** includes a glass substrate **31**, a color filter **32**, and touch detection electrodes TDL. The color filter **32** is provided on a first surface of the glass substrate **31**. The color filter **32** is configured of, for example, color filter layers of three colors of red (R), green (G), and blue (B) arranged periodically, where a set of three colors R, G, and B is associated with each display pixel. The touch detection electrodes TDL are provided on a second surface of the glass substrate **31**. The touch detection electrodes TDL, which are translucent, include for example, ITO. A polarizing plate **35** is disposed on the touch detection electrodes TDL.

The liquid crystal layer **6** acts as a display function layer that modulates light passing through the liquid crystal layer **6** depending on a state of an electric field. The electric field is formed by a difference in electric potential between the voltage of the drive electrode COML and the voltage of the pixel electrode **22**. A transverse-mode liquid crystal, such as fringe field switching (FFS) liquid crystal and in-plane switching (IPS) liquid crystal, is used for the liquid crystal layer **6**.

It is to be noted that an alignment film is provided between the liquid crystal layer **6** and the pixel substrate **2** and between the liquid crystal layer **6** and the counter substrate **3**, and an incidence-side polarizing plate is disposed on a bottom of the pixel substrate **2**, which are omitted to be shown herein.

FIG. **7** illustrates an exemplary configuration of a pixel structure of the liquid crystal display device **20**. The liquid crystal display device **20** has a plurality of pixels Pix arranged in a matrix. Each pixel Pix is configured of three sub-pixels SPix. The respective, three sub-pixels SPix are disposed in correspondence to the three colors (RGB) of the color filter **32** shown in FIG. **6**. Each sub-pixel SPix includes a TFT element Tr and a liquid crystal element LC. The TFT element Tr is configured of a thin film transistor which is an n-channel metal oxide semiconductor (MOS) TFT herein. A source of the TFT element Tr is connected to the pixel signal line SGL, a gate thereof is connected to the scan signal line GCL, and a drain thereof is connected to a first end of the liquid crystal element LC. A first end of the liquid crystal element LC is connected to the drain of the TFT element Tr, and the second end thereof is connected to the drive electrode COML.

The sub-pixel SPix is connected mutually with other sub-pixels SPix on the same row of the liquid crystal display device **20** through the scan signal line GCL. The scan signal line GCL is connected to the gate driver **12** and is supplied with the scan signal V_{scan} from the gate driver **12**. In addition, the sub-pixel SPix is connected mutually with other sub-pixels SPix on the same column of the liquid crystal display device **20** through the pixel signal line SGL. The pixel signal line SGL is connected to the selection switch section **14** and is supplied with the pixel signal V_{pix} from the selection switch section **14**.

Furthermore, the sub-pixel SPix is connected mutually with other sub-pixels SPix on the same row of the liquid crystal display device **20** through the drive electrode COML. The drive electrode COML is connected to the drive electrode driver **16** and is supplied with the drive signal V_{com} (DC drive signal V_{comDC}) from the drive electrode driver **16**.

According to such a configuration, in the liquid crystal display device **20**, the gate driver **12** drives the scan signal

lines GCL to be line-sequentially scanned in a time-divisional manner, thereby one horizontal line is sequentially selected, and the source driver 13 and the selection switch section 14 supply the pixel signals V_{pix} to pixels Pix along the one horizontal line, so that display is performed by one horizontal line basis.

FIG. 8 perspectively illustrates an exemplary configuration of the touch detection device 30. The touch detection device 30 is configured of the drive electrodes COML provided on the pixel substrate 2 and the touch detection electrodes TDL provided on the counter substrate 3. The drive electrodes COML are configured as a plurality of stripe-shaped electrode patterns extending in a horizontal direction in the figure. In the touch detection operation, the AC drive signal V_{comAC} is sequentially supplied to each of the electrode patterns by the drive electrode driver 16 so that the electrode patterns are driven to be sequentially scanned in a time-divisional manner as described below. The touch detection electrodes TDL are configured of stripe-shaped electrode patterns extending in a direction orthogonal to the extending direction of the electrode patterns of the drive electrodes COML. The electrode pattern of each of the touch detection electrode TDL is connected to input parts of the LPF section 42 of the touch detection section 40. The electrode patterns of the drive electrode COML intersect the electrode patterns of the touch detection electrode TDL, resulting in formation of capacitance at respective intersections.

According to such a configuration, in the touch detection device 30, the drive electrode driver 16 applies the AC drive signal V_{comAC} to the drive electrodes COML, so that the touch detection electrodes TDL output the touch detection signal V_{det} for touch detection. Specifically, the drive electrodes COML correspond to the drive electrode E1 in the basic principle of touch detection illustrated in FIGS. 1 to 3, and the touch detection electrodes TDL correspond to the touch detection electrode E2. The touch detection device 30 detects a touch event in accordance with the basic principle. As illustrated in FIG. 8, a capacitance-type touch sensor is formed in a matrix by the electrode patterns intersecting each other. Accordingly, a position of contact or proximity of an external proximity object is detected by scanning the entire touch detection surface of the touch detection device 30.

FIGS. 9A to 9C schematically illustrate touch detection scan. FIGS. 9A to 9C show application operation of the AC drive signal V_{comAC} to each of twenty drive electrode blocks B1 to B20 which define a display screen/touch detection surface herein. A drive-signal-applied block BAC indicates a drive electrode block B to which the AC drive signal V_{comAC} is applied, while the DC drive signal V_{comDC} is applied to other drive electrode blocks B. The drive electrode driver 16 sequentially selects a drive electrode block B as an object of touch detection operation and applies the AC drive signal V_{comAC} to the selected drive electrode block B so as to scan all the drive electrode blocks B, as shown in FIGS. 9A to 9C. During such operation, the drive electrode driver 16 applies the AC drive signal V_{comAC} to each drive electrode block B over a plurality of predetermined horizontal periods as described below. While the number of the drive electrode blocks B is twenty for convenience of description herein, this is not limitative.

FIG. 10 schematically illustrates display scan and touch detection scan. In the display panel with a touch detection function 1, the gate driver 12 drives the scan signal lines GCL to be line-sequentially scanned in a time-divisional manner so as to perform display scan $Scand$, and the drive

electrode driver 16 sequentially selects the drive electrode block B to be driven so as to perform touch detection scan $Scant$. Here, the touch detection scan $Scant$ is performed at a scan speed two times as high as the display scan $Scand$. In this way, in the display panel with a touch detection function 1, the scan speed of touch detection is higher than that of display scan, allowing a prompt response to a touch event due to an external proximity object, and leading to an improvement in response characteristics for touch detection. It is to be noted that the above scan is not limitative, and, for example, the touch detection scan $Scant$ may be performed at a scan speed two times or more as high as the display scan $Scand$, or may be performed at a scan speed two times or less as high as the display scan $Scand$.

(Drive Signal Generation Section 15 and Drive Electrode Driver 16)

FIG. 11 illustrates an exemplary configuration of the drive signal generation section 15. The drive signal generation section 15 includes a high-level-voltage generation sub-section 61, a low-level-voltage generation sub-section 62, buffers 63 to 65, and a switching circuit 66.

The high-level-voltage generation sub-section 61 generates a high-level voltage of the AC drive signal V_{comAC} . The low-level-voltage generation sub-section 62 generates a DC voltage of the DC drive signal V_{comDC} . The voltage generated by the low-level-voltage generation sub-section 62 is also used as a low-level voltage of the AC drive signal V_{comAC} . The buffer 63 outputs the voltage supplied from the high-level-voltage generation sub-section 61 to the switching circuit 66 while performing impedance conversion of the voltage. The buffer 64 outputs the voltage supplied from the low-level-voltage generation sub-section 62 to the switching circuit 66 while performing impedance conversion of the voltage. The switching circuit 66 generates the AC drive signal V_{comAC} based on the V_{com} control signal EXVCOM. In detail, if the V_{com} control signal EXVCOM is high, the switching circuit 66 outputs the voltage supplied from the buffer 63, and if the V_{com} control signal EXVCOM is low, it outputs the voltage supplied from the buffer 64. The buffer 65 outputs the voltage supplied from the low-level-voltage generation sub-section 62 as the DC drive signal V_{comDC} while performing impedance conversion of the voltage. The buffers 63 to 65 are each configured of a voltage follower, for example.

FIG. 12 illustrates an exemplary configuration of the drive electrode driver 16. The drive electrode driver 16 includes a scan control section 51, a touch detection scan section 52, and a drive section 530. The drive section 530 includes twenty drive sub-sections 53(1) to 53(20). Hereinafter, any one of the twenty drive sub-sections 53(1) to 53(20) is simply referred to as drive sub-section 53.

The scan control section 51 supplies a control signal to the touch detection scan section 52 based on a control signal supplied from the control section 11. In addition, the scan control section 51 has a function of supplying a V_{com} selection signal V_{COMSEL} to the drive section 530. The V_{com} selection signal V_{COMSEL} indicates appropriate one of the DC drive signal V_{comDC} and the AC drive signal V_{comAC} to be supplied to the drive electrodes COML.

The touch detection scan section 52 includes a shift register, and generates scan signals St for selecting the drive electrodes COML to which the AC drive signal V_{comAC} is applied. In detail, the touch detection scan section 52 generates a plurality of scan signals St corresponding to the drive electrode blocks B based on the control signal supplied from the scan control section 51, as described below. In the case where the touch detection scan section 52 supplies a

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high-level signal to a kth drive sub-section 53(k) as a kth scan signal $St(k)$, for example, the drive sub-section 53(k) applies the AC drive signal $VcomAC$ to a plurality of drive electrodes COML in a kth drive electrode block B(k).

The drive section 530 applies the DC drive signal $VcomDC$ or the AC drive signal $VcomAC$ supplied from the drive signal generation section 15 to the drive electrodes COML based on the scan signal St supplied from the touch detection scan section 52 and the $Vcom$ selection signal $VCOMSEL$ supplied from the scan control section 51. The drive sub-section 53 is provided by one in correspondence to each of the signals output from the touch detection scan section 52 so as to apply the drive signal $Vcom$ to a corresponding drive electrode block B.

The drive sub-section 53 includes an AND gate 54, an inverter 55, buffers 56 and 57, and switches SW1 and SW2. The AND gate 54 generates a logical product (AND) of the scan signal St supplied from the touch detection scan section 52 and the $Vcom$ selection signal $VCOMSEL$ supplied from the scan control section 51, and outputs the logical product. The inverter 55 generates an inverting logic of the signal output from the AND gate 54 and outputs the inverting logic. The buffer 56 has a function of amplifying the signal supplied from the AND gate 54 to an amplitude level allowing on/off control of the switch SW1. The switch SW1 is controlled to be on or off based on the signal supplied from the buffer 56, and has a first end to which the AC drive signal $VcomAC$ is supplied, and a second end connected to the plurality of drive electrodes COML defining the drive electrode block B. The buffer 57 has a function of amplifying the signal supplied from the inverter 55 to an amplitude level allowing on/off control of the switch SW2. The switch SW2 is controlled to be on or off based on the signal supplied from the buffer 57, and has a first end to which the DC drive signal $VcomDC$ is supplied, and a second end connected to the second end of the switch SW1.

According to such a configuration, if the scan signal St is high, the drive sub-section 53 outputs the AC drive signal $VcomAC$ as the drive signal $Vcom$ while the $Vcom$ selection signal $VCOMSEL$ is high, and outputs the DC drive signal $VcomDC$ as the drive signal $Vcom$ while the $Vcom$ selection signal $VCOMSEL$ is low. If the scan signal St is low, the drive sub-section 53 outputs the DC drive signal $VcomDC$ as the drive signal $Vcom$. The drive signal $Vcom$ output from the drive sub-section 53 in this way is supplied to a plurality of drive electrodes COML defining the drive electrode block B corresponding to the drive sub-section 53.

The liquid crystal element LC corresponds to a specific example of "display element" of the disclosure. The drive electrode driver 16 corresponds to a specific example of "drive section" of the disclosure. The high-level-voltage generation sub-section 61 and the buffer 63 correspond to a specific example of "first voltage generation sub-section" of the disclosure. The low-level-voltage generation sub-section 62 corresponds to a specific example of "second voltage generation sub-section" of the disclosure. The buffer 64 corresponds to a specific example of "buffer circuit" of the disclosure.

[Operations and Functions]

Operations and functions of the display panel with a touch detection function 1 according to the embodiment are now described.

(Summary of General Operation)

Summary of general operation of the display panel with a touch detection function 1 is described with reference to FIG. 4. The control section 11 supplies the control signal to each of the gate driver 12, the source driver 13, the drive

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signal generation section 15, the drive electrode driver 16, and the touch detection section 40 based on a video signal $Vdisp$ supplied from the outside, and thus controls those to operate in synchronization with one another. The gate driver 12 supplies the scan signals $Vscan$ to the liquid crystal display device 20 to sequentially select one horizontal line as a display drive object. The source driver 13 generates the pixel signal $Vsig$ with the pixel signals $Vpix$ multiplexed and the switching control signal $Vsel$ corresponding to the pixel signal $Vsig$, and supplies the generated signals to the selection switch section 14. The selection switch section 14 demultiplexes the pixel signals $Vpix$ based on the pixel signal $Vsig$ and the switching control signal $Vsel$, and supplies the pixel signals $Vpix$ to the respective pixels Pix defining the one horizontal line. The drive signal generation section 15 generates the DC drive signal $VcomDC$ and the AC drive signal $VcomAC$. The drive electrode driver 16 sequentially applies the AC drive signal $VcomAC$ to the drive electrode blocks B while applying the DC drive signal $VcomDC$ to the drive electrodes COML to which the AC drive signal $VcomAC$ is not applied. The display device with a touch detection function 10 performs display operation while performing touch detection operation so that the touch detection electrodes TDL output the touch detection signal $Vdet$. The LPF section 42 removes high frequency components (noise components) contained in the touch detection signal $Vdet$ to extract touch components for output. The A/D conversion section 43 converts the analog signals output from the LPF section 42 into digital signals. The signal processing section 44 detects presence of a touch event to the display device with a touch detection function 10 based on the signals output from the A/D conversion section 43. Upon detection of a touch event by the signal processing section 44, the coordinate extraction section 45 determines the touch-panel coordinates of the touch event. The detection timing control section 46 controls the LPF section 42, the A/D conversion section 43, the signal processing section 44, and the coordinate extraction section 45 to operate in synchronization with one another.

(Detailed Operation)

Detailed operation of the display panel with a touch detection function 1 is now described.

FIG. 13 illustrates an exemplary timing waveform of the display panel with a touch detection function 1, where (A) illustrates a waveform of the AC drive signal $VcomAC$, (B) illustrates a waveform of the DC drive signal $VcomDC$, (C) illustrates waveforms of the scan signal $Vscan$, (D) illustrates a waveform of the pixel signal $Vsig$, (E) illustrates waveforms of the switching control signal $Vsel$, (F) illustrates waveforms of the pixel signal $Vpix$, (G) illustrates a waveform of the $Vcom$ selection signal $VCOMSEL$, (H) illustrates waveforms of the drive signal $Vcom$, and (I) illustrates a waveform of the touch detection signal $Vdet$.

The display panel with a touch detection function 1 performs the display operation and the touch detection operation during each horizontal period (1H). In the display operation, the gate driver 12 sequentially applies the scan signal $Vscan$ to the scan signal lines GCL to perform display scan. In the touch detection operation, the drive electrode driver 16 sequentially applies the AC drive signal $VcomAC$ to the drive electrode blocks B by one at a time to perform touch detection scan, and the touch detection section 40 detects a touch event based on the touch detection signal $Vdet$ output from the touch detection electrodes TDL. These are described in detail below.

After start of one horizontal period (1H) at timing t_0 , the scan control section 51 of the drive electrode driver 16

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changes the voltage of the Vcom selection signal VCOMSEL from the low level to the high level at timing t1 ((G) of FIG. 13). As a result, in the drive electrode driver 16, the switch SW1 is turned on while the switch SW2 is turned off in a kth drive sub-section 53(k) relevant to the touch detection operation, so that the AC drive signal VcomAC ((A) of FIG. 13) generated by the drive signal generation section 15 is applied as a drive signal Vcom(B(k)) to the drive electrodes COML defining the corresponding kth drive electrode block B(k) through the switch SW1 ((H) of FIG. 13). In each of the drive sub-sections 53 other than the kth drive sub-section 53(k), the switch SW1 is turned off while the switch SW2 is turned on, so that the DC drive signal VcomDC ((B) of FIG. 13) generated by the drive signal generation section 15 is applied to the drive electrodes COML defining the corresponding drive electrode block B through the switch SW2 ((H) of FIG. 13).

The drive signal generation section 15 then changes the voltage of the AC drive signal VcomAC from the low level to the high level at timing t2 ((A) of FIG. 13). In detail, in the drive signal generation section 15, the buffer 63 supplies a current through the switching circuit 66 based on the Vcom control signal EXVCOM, so that the voltage of the AC drive signal VcomAC is changed from the low level to the high level. Along with this, the drive signal Vcom (B(k)) applied to the kth drive electrode block B(k) is also changed from the low level to the high level ((H) of FIG. 13). The drive signal Vcom (B(k)) is transmitted to the touch detection electrodes TDL through capacitance, so that the voltage of the touch detection signal Vdet is changed ((I) of FIG. 13).

The A/D conversion section 43 of the touch detection section 40 then performs A/D conversion of the signals output from the LPF section 42 which has received the touch detection signal Vdet, at a sampling timing is ((I) of FIG. 13). The signal processing section 44 of the touch detection section 40 detects a touch event based on the A/D conversion results collected over a plurality of horizontal periods as described below.

The drive signal generation section 15 then changes the voltage of the AC drive signal VcomAC from the high level to the low level at timing t3 ((A) of FIG. 13). In detail, in the drive signal generation section 15, the buffer 64 sinks the current through the switching circuit 66 based on the Vcom control signal EXVCOM, so that the voltage of the AC drive signal VcomAC is changed from the high level to the low level. Along with this, the drive signal Vcom (B(k)) applied to the kth drive electrode block B(k) is also changed from the high level to the low level ((H) of FIG. 13), so that the voltage of the touch detection signal Vdet is changed ((I) of FIG. 13).

Subsequently, the scan control section 51 of the drive electrode driver 16 changes the voltage of the Vcom selection signal VCOMSEL from the high level to the low level at timing t4 ((G) of FIG. 13). As a result, in the drive electrode driver 16, the switch SW1 is turned off while the switch SW2 is turned on in the drive sub-section 53(k), so that the DC drive signal VcomDC ((B) of FIG. 13) generated by the drive signal generation section 15 is applied as the drive signal Vcom(B(k)) to the drive electrodes COML defining the corresponding drive electrode block B(k) through the switch SW2 ((H) of FIG. 13).

The gate driver 12 applies the scan signal Vscan to an nth scan signal line GCL(n) relevant to display operation at timing t5, so that the voltage of the scan signal Vscan is changed from the low level to the high level ((C) of FIG. 13). In addition, the source driver 13 and the selection switch section 14 apply the pixel signals Vpix to the pixel signal

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lines SGL ((F) of FIG. 13) for display of pixels Pix on one horizontal line corresponding to the nth scan signal line GCL(n).

In detail, the gate driver 12 changes the scan signal Vscan from the low level to the high level at timing t5 to select one horizontal line relevant to the display operation. In addition, the source driver 13 supplies a pixel voltage VR for a red sub-pixel SPix as a pixel signal Vsig to the selection switch section 14 ((D) of FIG. 13), and generates a switching control signal VselR that is high during a period of supplying the pixel voltage VR, and supplies the switching control signal VselR to the selection switch section 14 ((E) of FIG. 13). The selection switch section 14 allows a switch SWR to be on in a period where the switching control signal VselR is high (write period PW) to separate the pixel voltage VR supplied from the source driver 13 from the pixel signal Vsig, and supplies the pixel voltage VR as a pixel signal VpixR to the red sub-pixels SPix on one horizontal line through the pixel signal line SGL ((F) of FIG. 13). It is to be noted that after the switch SWR is turned off, the pixel signal line SGL is floated and thus the voltage of the pixel signal line SGL is maintained ((F) of FIG. 13). Similarly, the source driver 13 supplies a pixel voltage VG for a green sub-pixel SPix together with a corresponding switching control signal VselG to the selection switch section 14 ((D) and (E) of FIG. 13). The selection switch section 14 demultiplexes the pixel voltage VG from the pixel signal Vsig based on the switching control signal VselG, and supplies the pixel voltage VG as a pixel signal VpixG to the green sub-pixels SPix on one horizontal line through the pixel signal line SGL ((F) of FIG. 13). Similarly, the source driver 13 then supplies a pixel voltage VB for a blue sub-pixel SPix together with a corresponding switching control signal VselB to the selection switch section 14 ((D) and (E) of FIG. 13). The selection switch section 14 demultiplexes the pixel voltage VB from the pixel signal Vsig based on the switching control signal VselB, and supplies the pixel voltage VB as a pixel signal VpixB to the blue sub-pixels SPix on one horizontal line through the pixel signal line SGL ((F) of FIG. 13).

Next, the gate driver 12 changes the scan signal Vscan(n) of the scan signal line GCL (n) in the nth row from the high level to the low level at timing t6 ((C) of FIG. 13). As a result, the sub-pixels SPix on the one horizontal line relevant to display operation are electrically separated from the pixel signal lines SGL.

Then, one horizontal period is finished and a subsequent horizontal period is started at timing t10.

After that, the above operation is repeated, thereby the display panel with a touch detection function 1 performs display operation over the entire display surface through line-sequential scan, and performs touch detection operation over the entire touch-detection surface through scanning the drive electrode blocks B by one at a time.

FIG. 14 illustrates an exemplary operation of the touch detection scan, where (A) illustrates a waveform of the AC drive signal VcomAC, (B) illustrates a waveform of the DC drive signal VcomDC, (C) illustrates a waveform of the Vcom selection signal VCOMSEL, (D) illustrates waveforms of the scan signal St, (E) illustrates waveforms of the drive signal Vcom, and (F) illustrates a waveform of the touch detection signal Vdet.

As shown in FIG. 14, the drive electrode driver 16 sequentially applies the AC drive signal VcomAC to the corresponding drive electrode block B ((E) of FIG. 14) based on the scan signal St ((D) of FIG. 14) generated by the touch detection scan section 52 to perform touch detection

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scan. During this, the drive electrode driver 16 applies the AC drive signal V_{comAC} to each of the drive electrode blocks B over a plurality of predetermined horizontal periods ((E) of FIG. 14). The touch detection section 40 samples the touch detection signal V_{det} based on the AC drive signal V_{comAC} during each one horizontal period. After such sampling is finished in the last horizontal period among the plurality of predetermined horizontal periods, the signal processing section 44 detects presence of a touch event in a region corresponding to the relevant drive electrode block B based on the plurality of sampling results. In this way, touch detection is performed based on the plurality of sampling results. As a result, the sampling results are statistically analyzed. This suppresses a reduction in an S/N ratio due to variations in the sampling results, leading to an improvement in accuracy of touch detection.

COMPARATIVE EXAMPLE

The functions of the display panel with a touch detection function 1 according to the embodiment are now described in comparison with a display panel with a touch detection function according to a comparative example. In the comparative example, a drive signal generation section generates high and low, two kinds of DC drive signals, and a drive electrode driver selects one of the two DC drive signals and applies the selected DC drive signal to drive electrodes COML. Other configurations are the same as in the embodiment (FIG. 4 and others).

FIG. 15 illustrates an exemplary configuration of a drive signal generation section 15R according to the comparative example. The drive signal generation section 15R generates two kinds of DC drive signals V_{comH} and V_{comDC} . The DC drive signal V_{comH} is generated by a high-level-voltage generation sub-section 61 and output through a buffer 63. The DC drive signal V_{comDC} is generated by a low-level-voltage generation sub-section 62 and output through a buffer 65.

FIG. 16 illustrates an exemplary configuration of a drive electrode driver 16R according to the comparative example. The drive electrode driver 16R includes a scan control section 51R. The scan control section 51R supplies a Vcom selection signal $V_{COMSELR}$ to a drive section 530. The Vcom selection signal $V_{COMSELR}$ indicates appropriate one of the two kinds of DC drive signals V_{comH} and V_{comDC} to be supplied to the drive electrodes COML.

The drive electrode driver 16R has switches SW1 each having one end to which the DC drive signal V_{comH} is supplied, as shown in FIG. 16. According to such a configuration, if a scan signal S_t is high, the drive sub-section 53 outputs the DC drive signal V_{comH} as a drive signal V_{com} while the Vcom selection signal $V_{COMSELR}$ is high, and outputs the DC drive signal V_{comDC} as the drive signal V_{com} while the Vcom selection signal $V_{COMSELR}$ is low.

FIG. 17 illustrates an exemplary timing waveform of the display panel with a touch detection function according to the comparative example, where (A) illustrates a waveform of the DC drive signal V_{comH} , (B) illustrates a waveform of the DC drive signal V_{comDC} , (C) illustrates waveforms of a scan signal V_{scan} , (D) illustrates a waveform of a pixel signal V_{sig} , (E) illustrates waveforms of a switching control signal V_{sel} , (F) illustrates waveforms of a pixel signal V_{pix} , (G) illustrates a waveform of the Vcom selection signal $V_{COMSELR}$, (H) illustrates waveforms of a drive signal V_{com} , and (I) illustrates a waveform of a touch detection signal V_{det} .

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The scan control section 51R of the drive electrode driver 16R changes the voltage of the Vcom selection signal $V_{COMSELR}$ from the low level to the high level at timing t_{11} ((G) of FIG. 17). As a result, in the drive electrode driver 16, the switch SW1 is turned on while a switch SW2 is turned off in a kth drive sub-section 53(k) relevant to the touch detection operation, so that the DC drive signal V_{comH} ((A) of FIG. 17) generated by the drive signal generation section 15R is applied as a drive signal $V_{com(B(k))}$ to the drive electrodes COML defining the corresponding kth drive electrode block B(k) through the switch SW1 ((H) of FIG. 17). In detail, the buffer 63 of the drive signal generation section 15R supplies a current to the drive electrodes COML, so that the drive signal $V_{com(B(k))}$ is changed from the low level to the high level. In each of the drive sub-sections 53 other than the drive sub-section 53(k), the switch SW1 is turned off while the switch SW2 is turned on, so that the DC drive signal V_{comDC} ((B) of FIG. 17) generated by the drive signal generation section 15R is applied to the drive electrodes COML defining the corresponding drive electrode block B through the switch SW2 ((H) of FIG. 17). An A/D conversion section 43 of a touch detection section 40 then performs A/D conversion of the signals output from an LPF section 42 which has received the touch detection signal V_{det} , at a sampling timing is ((I) of FIG. 17).

The scan control section 51R of the drive electrode driver 16R changes the voltage of the Vcom selection signal $V_{COMSELR}$ from the high level to the low level at timing t_{12} ((G) of FIG. 17). As a result, in the drive electrode driver 16R, the switch SW1 is turned off while the switch SW2 is turned on in the kth drive sub-section 53(k), so that the DC drive signal V_{comDC} ((B) of FIG. 17) generated by the drive signal generation section 15R is applied as the drive signal $V_{com(B(k))}$ to the drive electrodes COML defining the corresponding drive electrode block B(k) through the switch SW2 ((H) of FIG. 17). In detail, the buffer 65 of the drive signal generation section 15R sinks the current from the drive electrodes COML, so that the voltage of the drive signal $V_{com(B(k))}$ is changed from the high level to the low level.

At that time, the buffer 65 of the drive signal generation section 15R drives all the drive electrodes COML through the switches SW2 of the drive section 530 of the drive electrode driver 16R. Thus, the buffer 65 may not sufficiently drive the drive electrodes COML due to a large load. In such a case, at and after timing t_2 , electric charge, which has been accumulated in the drive electrodes COML of the drive electrode block B(k) during application of the DC drive signal V_{comH} , moves to other drive electrode blocks B through the switch SW2 of the drive sub-section 53(k), resulting in rising of the voltage of the drive signal V_{com} ($V_{com(B(k-1))}$, $V_{com(B(k))}$, $V_{com(B(k+1))}$ and others) applied to the drive electrode blocks B (wavy portions WR). The buffer 65 sinks such electric charge, so that the voltage of the drive signal V_{com} gradually converges to the voltage level of the DC drive signal V_{comDC} . If such converging time is long, nearly the write period PW, the pixel signal V_{pix} is insufficiently written into the pixels during the relevant write period PW, leading to a possibility of a reduction in image quality.

Contrarily, in the display panel with a touch detection function according to the embodiment, as shown in (H) of FIG. 13, the AC drive signal V_{comAC} is changed from the high level to the low level at timing t_3 , and then the switch SW1 is turned off while the switch SW2 is turned on at timing t_4 in the drive sub-section 53(k), so that the drive

signal supplied to the drive electrodes COML is switched from the AC drive signal VcomAC to the DC drive signal VcomDC.

As a result, in the drive signal generation section 15, the buffer 64, which is different from the buffer 65 generating the DC drive signal VcomDC, sinks the current at the timing when the AC drive signal VcomAC is changed from the high level to the low level at timing t3, and therefore the DC drive signal VcomDC is less affected by the AC drive signal VcomAC. Specifically, noise in the DC drive signal VcomDC, which is supplied to the horizontal line to which display operation is performed, is suppressed, thereby suppressing a reduction in image quality.

In addition, since the electric potential of the drive electrode block B(k) (the low-level voltage of the AC drive signal VcomAC) is substantially equal to the electric potential of other drive electrode blocks B(k) (the DC voltage of the DC drive signal VcomDC) immediately before the timing t4, substantially no electric charge moves after the switch SW2 is turned on at the timing t4. This reduces rising of the voltage of the drive signal Vcom (B(k)) as shown in the wavy portions WR in the comparative example, thereby suppressing a reduction in image quality.

[Effect]

As described before, in the embodiment, the AC drive signal and the DC drive signal are selectively applied to the drive electrodes to be driven, and the DC drive signal is switched from the AC drive signal after the AC drive signal is changed from the high level to the low level, thereby suppressing a reduction in image quality.

In addition, in the embodiment, the buffer for supplying the low level of the AC drive signal and the buffer for supplying the DC drive signal are separately provided, thereby suppressing a reduction in image quality.

[Modification 1-1]

While the drive signal generation section 15 is configured as shown in FIG. 11 in the first embodiment, this is not limitative. For example, a buffer 64A for generating the low level of the AC drive signal may receive the DC drive signal VcomDC, as shown in FIG. 18. The low-level-voltage generation sub-section 62 and the buffer 65 correspond to a specific example of “second voltage generation section” of the disclosure. The buffer 64A corresponds to a specific example of “buffer circuit” of the disclosure. In this case, the DC drive signal VcomDC is also less affected by the noise due to the AC drive signal VcomAC, thereby suppressing a reduction in image quality.

[Modification 1-2]

While the drive electrode driver 16 drives the drive electrode blocks B, each including the predetermined number of drive electrodes COML, by one at a time in the first embodiment, this is not limitative. Instead, the drive electrode driver 16 may directly drive the drive electrodes COML by one at a time, for example, as shown in FIG. 19. In such a case, a drive section 530B includes the same number of drive sub-sections 53 as the total number of the drive electrodes COML, and a touch detection scan section 52B supplies the scan signals St to the drive section 530B.

[Modification 1-3]

While the drive electrodes COML are scanned to be driven by one drive-electrode-block B, which includes the predetermined number of drive electrodes COML, at a time, this is not limitative. Instead, for example, a predetermined number of drive electrodes COML may be simultaneously driven while the drive electrodes COML to be driven are shifted one by one to scan the drive electrodes COML. This is described in detail below.

FIG. 20 schematically illustrates an exemplary operation of a drive electrode driver 16C according to the modification. The drive electrode driver 16C simultaneously applies the AC drive signal VcomAC to a predetermined number of drive electrodes COML. In detail, the drive electrode driver 16C simultaneously applies the AC drive signal VcomAC to the predetermined number (here, five) of drive electrodes COML (drive-signal-applied electrodes LAC). Then, the drive electrode driver 16C shifts the drive electrodes COML, to which the AC drive signal VcomAC is applied, one by one to perform touch detection scan. Such touch detection scan is achieved by, for example, using the drive electrode driver 16B shown in FIG. 19, where a shift register in the touch detection scan section 52B transmits a wide pulse. While the AC drive signal VcomAC is simultaneously applied to the five drive electrodes COML herein, this is not limitative. Instead, the AC drive signal VcomAC may be simultaneously applied to not more than four drive electrodes COML or not less than six drive electrodes COML. While the drive electrodes COML, to which the AC drive signal VcomAC is applied, are shifted one by one herein, this is not limitative. Instead, the drive electrodes COML may be shifted by two or more at a time.

[Modification 1-4]

While the voltage of the AC drive signal VcomAC is changed from the low level to the high level at timing t2 after the voltage of the Vcom selection signal VCOMSEL is changed from the low level to the high level at timing t1 as shown in FIG. 13 in the first embodiment, this is not limitative. For example, the voltage of the Vcom selection signal VCOMSEL may be changed from the low level to the high level at timing t22 after the voltage of the AC drive signal VcomAC is changed from the low level to the high level at timing t21, as shown in FIG. 21.

[3. Second Embodiment]

A display panel with a touch detection function 7 according to a second embodiment is now described. The second embodiment is different from the first embodiment in a selection process of the drive signal in the case where one of the DC drive signal VcomDC and the AC drive signal VcomAC is selected to be supplied to the drive electrodes COML. It is to be noted that substantially the same components as those of the display panel with a touch detection function 1 according to the first embodiment are designated by the same numerals, and description of them is appropriately omitted.

FIG. 22 illustrates an exemplary configuration of a drive electrode driver 18 of the display panel with a touch detection function 7. The drive electrode driver 18 includes a scan control section 71 and a drive section 730.

The scan control section 71 supplies a control signal to a touch detection scan section 52 based on a control signal supplied from a control section 11.

The drive section 730 applies a drive signal Vcom (a DC drive signal VcomDC or an AC drive signal VcomAC) to the drive electrodes COML based on a scan signal St supplied from the touch detection scan section 52. Each drive sub-section 73 includes an inverter 55, buffers 56 and 57, and switches SW1 and SW2. Specifically, the drive sub-section 73 does not include an AND gate 54 unlike the drive sub-section 53 in the first embodiment. According to such a configuration, the drive sub-section 73 outputs the AC drive signal VcomAC as the drive signal Vcom if the scan signal St is high, and outputs the DC drive signal VcomDC as the drive signal Vcom if the scan signal St is low.

FIG. 23 illustrates an exemplary timing waveform of the display panel with a touch detection function 7, where (A)

illustrates a waveform of the AC drive signal V_{comAC} , (B) illustrates a waveform of the DC drive signal V_{comDC} , (C) illustrates waveforms of the scan signal V_{scan} , (D) illustrates a waveform of a pixel signal V_{sig} , (E) illustrates waveforms of a switching control signal V_{sel} , (F) illustrates waveforms of a pixel signal V_{pix} , (G) illustrates waveforms of the drive signal V_{com} , and (H) illustrates a waveform of a touch detection signal V_{det} .

Upon start of one horizontal period (1H) at timing t_0 , the drive electrode driver **18** supplies the AC drive signal V_{comAC} to the drive electrodes COML relevant to touch detection ((G) of FIG. **23**). In detail, in the drive electrode driver **18**, the switch SW1 is turned on while the switch SW2 is turned off in a kth drive sub-section **73(k)** relevant to the touch detection operation, so that the AC drive signal V_{comAC} ((A) of FIG. **23**) generated by the drive signal generation section **15** is applied as a drive signal $V_{com}(B(k))$ to the drive electrodes COML defining the corresponding kth drive electrode block B(k) through the switch SW1 ((G) of FIG. **23**).

The drive signal generation section **15** then changes the voltage of the AC drive signal V_{comAC} from the low level to the high level at timing t_2 ((A) of FIG. **23**). Along with this, the drive signal $V_{com}(B(k))$ applied to the kth drive electrode block B(k) is changed from the low level to the high level ((G) of FIG. **23**). The drive signal $V_{com}(B(k))$ is transmitted to touch detection electrodes TDL through capacitance, so that the voltage of the touch detection signal V_{det} is changed ((H) of FIG. **23**). An A/D conversion section **43** of a touch detection section **40** then performs A/D conversion of the signals output from an LPF section **42** which has received the touch detection signal V_{det} , at a sampling timing is ((H) of FIG. **23**). The drive signal generation section **15** then changes the voltage of the AC drive signal V_{comAC} from the high level to the low level at timing t_3 ((A) of FIG. **23**).

At and after timing t_5 , the display panel with a touch detection function **7** performs display operation as in the display panel with a touch detection function **1** according to the first embodiment. In the display panel with a touch detection function **7**, the drive electrode driver **18** still applies the AC drive signal V_{comAC} as the drive signal $V_{com}(B(k))$ to the drive electrodes COML relevant to the touch detection during a period of the display operation ((G) of FIG. **23**).

FIG. **24** illustrates an exemplary operation of the touch detection scan of the display panel with a touch detection function **7**, where (A) illustrates a waveform of the AC drive signal V_{comAC} , (B) illustrates a waveform of the DC drive signal V_{comDC} , (C) illustrates waveforms of the scan signal St , (D) illustrates waveforms of the drive signal V_{com} , and (E) illustrates a waveform of the touch detection signal V_{det} .

As shown in FIG. **24**, the drive electrode driver **18** sequentially applies the AC drive signal V_{comAC} to the relevant drive electrode block B based on the scan signal St ((C) of FIG. **24**) generated by the touch detection scan section **52** ((D) of FIG. **24**) to perform touch detection scan. In this operation, the drive electrode driver **18** continuously supplies the AC drive signal V_{comAC} to the corresponding kth drive electrode block B(k) during a period where the kth scan signal $St(k)$ is high, for example. Specifically, in the first embodiment, the AC drive signal V_{comAC} is applied only while the V_{com} selection signal V_{COMSEL} is high in the period where the kth scan signal $St(k)$ is high, as shown in (E) of FIG. **14**. Contrarily, in the second embodiment, the

AC drive signal V_{comAC} is continuously applied in the period where the kth scan signal $St(k)$ is high, as shown in (D) of FIG. **24**.

The AC drive signal V_{comAC} or the DC drive signal V_{comDC} is applied to the drive electrode COML along one horizontal line relevant to the display operation. In detail, in the case where the drive electrode COML along one horizontal line relevant to the display operation is not included in the drive detection block B relevant to touch detection operation, the DC drive signal V_{comDC} is applied to the drive electrode COML. Contrarily, the drive electrode COML along one horizontal line relevant to the display operation is included in the drive detection block B relevant to the touch detection operation at the timing $W1$ in FIG. **10**. In such a case, the AC drive signal V_{comAC} is applied to the drive electrode COML. The DC voltage of the DC drive signal V_{comDC} and the low-level voltage of the AC drive signal V_{comAC} are generated by the low-level-voltage generation sub-section **62** of the drive signal generation section **15** as shown in FIG. **11** and thus have substantially the same voltage level. In this way, since the voltage of the drive electrode COML along one horizontal line relevant to the display operation is substantially the same between the case where the one horizontal line corresponds to the drive detection block B relevant to the touch detection operation and another case, substantially the same pixel signal is written during the write period PW, thereby suppressing a reduction in image quality.

It is to be noted that in the case where the DC voltage of the DC drive signal V_{comDC} is slightly different from the low-level voltage of the AC drive signal V_{comAC} due to a difference in performance between the buffers **64** and **65** (FIG. **11**), the voltage is differently written into a pixel between the case where the DC drive signal V_{comDC} is supplied to the drive electrode COML along one horizontal line relevant to the display operation and the case where the AC drive signal V_{comAC} is supplied thereto, leading to a possibility of degradation in image quality. In such a case, the AC drive signal V_{comAC} is desirably applied to the drive electrode COML during periods other than the write period PW as in the display panel with a touch detection function **1** of the first embodiment.

As described above, in the second embodiment, the drive signal supplied to the drive electrode is selected only based on the scan signal St , which simplifies the configurations of the scan control section and the drive section. Other effects are the same as in the first embodiment.

[Modification 2]

In the second embodiment, the drive signal generation section **15** may be configured as shown in FIG. **18**, for example, as in the modification 1-1 of the first embodiment. In addition, the drive electrode driver **18** may directly drive the drive electrodes COML by one at a time as in the modification 1-2 of the first embodiment. In addition, touch detection scan may be performed as shown in FIG. **20** as in the modification 1-3 of the first embodiment.

[3. Application Examples]

Next, application examples of each display panel with a touch detection function in the above-described embodiments and modifications are now described with reference to FIGS. **25** to **29G**. The display panel with a touch detection function described in the embodiments and others is applicable to electronic units in various fields, including a television apparatus, a digital camera, a notebook personal computer, a mobile terminal device such as a mobile phone, and a video camera. In other words, the display panel with a touch detection function in the embodiments and others is

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applicable to electronic units in various fields for displaying externally-input or internally-generated video signals as still or video images.

APPLICATION EXAMPLE 1

FIG. 25 shows appearance of a television apparatus applied with the display panel with a touch detection function according to the embodiments and others. The television apparatus has, for example, an image display screen section 510 including a front panel 511 and a filter glass 512. The image display screen section 510 is configured of the display panel with a touch detection function according to the embodiments and others.

APPLICATION EXAMPLE 2

FIGS. 26A and 26B show appearance of a digital camera applied with the display panel with a touch detection function according to the embodiments and others. The digital camera has, for example, a light emitting section for flash 521, a display section 522, a menu switch 523, and a shutter button 524. The display section 522 is configured of the display panel with a touch detection function according to the embodiments and others.

APPLICATION EXAMPLE 3

FIG. 27 shows appearance of a notebook personal computer applied with the display panel with a touch detection function according to the embodiments and others. The notebook personal computer has, for example, a main body 531, a keyboard 532 for input operation of letters and the like, and a display section 533 for displaying images. The display section 533 is configured of the display panel with a touch detection function according to the embodiments and others.

APPLICATION EXAMPLE 4

FIG. 28 shows appearance of a video camera applied with the display panel with a touch detection function according to the embodiments and others. The video camera has, for example, a main body section 541, an object-shooting lens 542 provided on a front side face of the main body section 541, a start/stop switch 543 for shooting, and a display section 544. The display section 544 is configured of the display panel with a touch detection function according to the embodiments and others.

APPLICATION EXAMPLE 5

FIGS. 29A to 29G show appearance of a mobile phone applied with the display panel with a touch detection function according to the embodiments and others. For example, the mobile phone is configured of an upper housing 710 and a lower housing 720 connected to each other by a hinge section 730, and has a display 740, a sub display 750, a picture light 760, and a camera 770. The display 740 or the sub display 750 is configured of the display panel with a touch detection function according to the embodiments and others.

While the present technology has been described with the several embodiments, the modifications, and the application examples to electronic units hereinbefore, the technology is not limited to the embodiments and others, and various modifications or alterations may be made.

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For example, while the drive electrodes COML are provided on the TFT substrate 21 and the pixel electrodes 22 are provided on the drive electrodes COML with the insulating film 23 therebetween as shown in FIG. 6 in the embodiments and others, this is not limitative. Instead, for example, the pixel electrodes 22 may be provided on the TFT substrate 21, and the drive electrodes COML may be provided on the pixel electrodes 22 with the insulating film 23 therebetween.

For example, while the touch detection device is integrated with the liquid crystal display device including liquid crystal of a transverse electric mode such as a FFS mode and an IPS mode in the embodiments and others, the touch detection device may be integrated with a liquid crystal display device including liquid crystal of various modes such as a twisted nematic (TN) mode, a vertical alignment (VA) mode, and an electrically controlled birefringence (ECB) mode instead. In the case where such liquid crystal is used, the display device with a touch detection function is configured as shown in FIG. 30. FIG. 30 illustrates an exemplary sectional structure of a major part of a display device with a touch detection function 10D, showing a configuration where a liquid crystal layer 6B is sandwiched between a pixel substrate 2B and a counter substrate 3B. Since names and functions of other sections are similar to those shown in the case of FIG. 6, description of them is omitted. This example is different from the case of FIG. 6 in that the drive electrodes COML used for both display and touch detection are provided on the counter substrate 3B.

In addition, while, for example, a so-called in-cell type display device, where a liquid crystal display device is integrated with a capacitance-type touch detection device, is used in the above-described embodiments and others, this is not limitative. Instead, for example, a so-called on-cell type display device, where the capacitance-type touch detection device is mounted on the surface of the liquid crystal display device, may be used. In the on-cell type display device, for example, in the case where noise in touch detection drive is transmitted from the touch detection device to the liquid crystal display device, the noise is reduced through the driving as in the embodiments, leading to suppression of a reduction in image quality of the liquid crystal display device.

In addition, for example, while the liquid crystal elements are used for the display elements in the above-described embodiments and others, this is not limitative. Instead, electro luminescence (EL) elements may be used, for example.

It is possible to achieve at least the following configurations from the above-described exemplary embodiments and the modifications of the disclosure.

(1) A display panel with a touch detection function including:

one or more display elements;
 one or more drive electrodes;
 one or more touch detection electrodes; and
 a drive section selectively applying a DC drive signal or an AC drive signal to the drive electrodes.

(2) The display panel according to (1), wherein the display elements perform write operation for display during a write period,

the AC drive signal has a pulse waveform that transits from a first voltage to a second voltage corresponding to a DC voltage level of the DC drive signal at a transition timing in a period other than the write period,

the drive section applies the AC drive signal to the drive electrodes in an enable period including the transition tim-

ing, and applies the DC drive signal to the drive electrodes in a period other than the enable period to perform touch detection drive.

(3) The display panel according to (2), wherein the AC drive signal has a pulse waveform that includes the first voltage in a pulse period different from the write period, and includes the second voltage in a period other than the pulse period, and

the transition timing corresponds to end timing of the pulse period.

(4) The display panel according to (3), wherein the enable period is in a period other than the write period.

(5) The display panel according to (3) or (4), wherein the enable period includes the pulse period.

(6) The display panel according to (3), wherein the plurality of display elements are arranged in a matrix and line-sequentially scanned for display operation, and

the enable period corresponds to one horizontal period or consecutive, multiple horizontal periods.

(7) The display panel according to any one of (1) to (6), further including

a drive signal generation section generating the DC drive signal and the AC drive signal,

wherein the drive signal generation section includes a first-voltage generation sub-section generating the first voltage,

a second-voltage generation sub-section generating a voltage corresponding to a DC voltage level of the DC drive signal,

a buffer circuit generating the second voltage based on the voltage output from the second voltage generation sub-section, and

a switching circuit generating the AC drive signal through switching the first voltage and the second voltage from each other.

(8) The display panel according to any one of (2) to (7), further including

a touch detection section, wherein the drive electrodes are formed to extend in a predetermined direction,

the touch detection electrodes are formed to extend in a direction crossing the extending direction of the drive electrodes in a layer different from a layer of the drive electrodes, and

the drive section sequentially selects one or more drive electrodes among the drive electrodes as a drive object electrode, and drives the drive object electrode for touch detection while applying the DC drive signal to drive electrodes other than the drive object electrode, and

the touch detection section detects a touch event based on signals output from the touch detection electrodes.

(9) The display panel according to any one of (1) to (8), wherein the display element includes a liquid crystal layer, and

a pixel electrode provided between the liquid crystal layer and the drive electrodes, or disposed facing the liquid crystal layer with the drive electrodes therebetween.

(10) The display panel according to any one of (1) to (8), wherein the display element includes

a liquid crystal layer, and a pixel electrode disposed facing the drive electrodes with the liquid crystal layer therebetween.

(11) A method of driving a display panel with a touch detection function, including:

driving one or more display elements for display; and

selectively applying a DC drive signal or an AC drive signal to one or more drive electrodes.

(12) A drive circuit including:

a display drive section driving one or more display elements; and

a touch detection drive section selectively applying a DC drive signal or an AC drive signal to one or more drive electrodes.

(13) An electronic unit including:

a display panel with a touch detection function; and a control section controlling operation using the display panel with a touch detection function,

wherein the display panel with a touch detection function includes

one or more display elements,

one or more drive electrodes,

one or more touch detection electrodes, and

a drive section selectively applying a DC drive signal or an AC drive signal to the drive electrodes.

The present disclosure contains subject matter related to that disclosed in Japanese Priority Patent Application JP 2011-89429 filed in the Japan Patent Office on Apr. 13, 2011 and Japanese Priority Patent Application JP 2011-242797 filed in the Japan Patent Office on Nov. 4, 2011, the entire content of which is hereby incorporated by reference.

It should be understood by those skilled in the art that various modifications, combinations, sub-combinations and alterations may occur depending on design requirements and other factors insofar as they are within the scope of the appended claims or the equivalents thereof.

What is claimed is:

1. A display panel with a touch detection function comprising:

one or more display elements;

one or more drive electrodes;

a drive section selectively applying a DC drive signal or an AC drive signal to the drive electrodes;

wherein

the display elements perform write operation for display during a write period,

the drive section applies the AC drive signal to the drive electrodes in order to perform touch detection drive in a period other than the write period,

when a scan signal is high, the drive section outputs the AC drive signal while a selection signal is high, and when the scan signal is low, the drive section outputs the DC drive signal while the selection signal is low.

2. The display panel according to claim 1, wherein, the AC drive signal has a pulse waveform that transits from the first voltage to the second voltage corresponding to a DC voltage level of the DC drive signal at a transition timing in a period other than the write period, the drive section applies the AC drive signal to the drive electrodes in an enable period including the transition timing, and applies the DC drive signal to the drive electrodes in a period other than the enable period to perform touch detection drive.

3. The display panel according to claim 2, further comprising,

a touch detection section,

wherein the drive electrodes are formed to extend in a predetermined direction, and

the drive section sequentially selects one or more of the drive electrodes among the drive electrodes as a drive object electrode, and drives the drive object electrode

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for touch detection while applying the DC drive signal to the drive electrodes other than the drive object electrode.

4. The display panel according to claim 1, wherein at least one of the display elements includes a liquid crystal layer, and a pixel electrode provided between the liquid crystal layer and the drive electrodes, or disposed facing the liquid crystal layer with the drive electrodes therebetween.

5. The display panel according to claim 1, wherein at least one of the display elements includes a liquid crystal layer, and a pixel electrode disposed facing the drive electrodes with the liquid crystal layer therebetween.

6. An electronic unit comprising:
a display panel with a touch detection function; and
a control section controlling operation using the display panel with a touch detection function,
wherein the display panel with a touch detection function includes
one or more display elements,
one or more drive electrodes,
a drive section selectively applying a DC drive signal or an AC drive signal to the drive electrodes,
wherein
the display elements perform write operation for display during a write period,
the drive section applies the AC drive signal to the drive electrodes in order to perform touch detection drive in a period other than the write period,

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when a scan signal is high, the drive section outputs the AC drive signal while a selection signal is high, and when the scan signal is low, the drive section outputs the DC drive signal while the selection signal is low.

7. The display panel according to claim 1, wherein the switch element includes:

a first switch element disposed between the first wiring and at least one of the drive electrodes; and

a second switch element disposed between the second wiring and said at least one of the drive electrodes, the first switch performs on/off control of the DC drive signal to be applied to said at least one of the drive electrodes, and

the second switch performs on/off control of the AC drive signal to be applied to said at least one of the drive electrodes.

8. The electronic unit according to claim 6, wherein the switch element includes:

a first switch element disposed between the first wiring and one of the drive electrodes; and

a second switch element disposed between the second wiring and said one of the drive electrodes, the first switch performs on/off control of the DC drive signal to be applied to said one of the drive electrodes, and

the second switch performs on/off control of the AC drive signal to be applied to said one of the drive electrodes.

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